W.P.

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AN ANALYSIS OF THE INTERNATIONAL GREAT LAKES LEVELS BOARD REPORT ON REGULATION OF GREAT LAKES WATER LEVELS

Navigation

Water Resources Management Workshop
and
Lake Superior Project

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University of Wisconsin Madison

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January 1977

WISCONSIN
COASTAL MANAGEMENT

Wisconsin Coastal Management Program

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AN ANALYSIS OF THE INTERNATIONAL GREAT LAKES LEVELS BOARD REPORT ON REGULATION OF GREAT LAKES WATER LEVELS

NAVIGATION

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RF Monograph 76-02

IES WORKING PAPER 28

Rockefeller Lake Superior Project
Water Resources Management Workshop
Institute for Environmental Studies
University of Wisconsin-Madison

January 1977

This research was made possible by a grant to the Institute for Environmental Studies from the Rockefeller Foundation, Grant Number RF 74099. Additional support was received through the Wisconsin Coastal Program under the Coastal Zone Management Act of 1972 administered by the National Oceanic and Atmospheric Administration.

Other working papers in this series include the following:

RF Monograph 76-01
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IES Working Paper 30 — Wetlands, Fisheries, and Water Quality

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These papers are based upon research completed in December 1975.

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ACKNOWLEDGMENTS

The authors wish to particularly thank the following individuals for their valuable assistance:

CENTER FOR GREAT LAKES STUDY

H. S. Brockel
H. Mayer
E. Schenker

WISCONSIN DEPARTMENT OF TRANSPORTATION

P. Winkel

SUPERIOR PORT DIRECTOR

J. Salter

U.S. ARMY CORPS OF ENGINEERS — NORTH CENTRAL DIVISION

G. Lykowski

U.S. ARMY CORPS OF ENGINEERS — DETROIT DISTRICT

G. Larson

This paper is one of six working documents that were prepared in the summer of 1975 as part of the Water Resources Management Workshop of the University of Wisconsin-Madison.

We wish to thank all the individuals who reviewed the draft documents and appreciate the helpful comments.

I. STATEMENT OF THE PROBLEM

In 1964 the International Joint Commission (IJC) asked the International Great Lakes Levels Board (IGLLB) to study plans for further regulation of Great Lakes water levels for the benefit of all interest groups. One major interest is navigation. During the spring and late fall, especially during periods of low supply to the lakes, a cargo ship cannot load to capacity. If regulation raises the water level 1" or more the ships can load additional cargo and reduce their unit transportation cost. This is a *real* benefit to navigation.

Appendix E of the Levels Board report, Commercial Navigation, documents the method used to assess the potential benefit or loss to shipping from changes in lake levels regimes (IGLLB 1973, Appendix E). It contains the evaluation of the economic effects on navigation due to changes that would take place under selected regulation plans. The Levels Board calculated the average annual benefits to commercial navigation during the years 1972-2022 for the various proposed regulation plans; these benefits vary from $273,000 for regulation Plan SHMEO-38 to $927,000 for Plan SO-901.

The University Work Group analyzed the navigation benefits that the IGLLB estimated will accrue from Plan SO-901 as compared to the Basis of Comparison (BOC) plan.* The analysis questions when and how navigational benefits result from the lake levels under these regulation plans. The University Work Group critically examined the data base, the IGLLB's methodology, and the assumptions underpinning the benefit estimates.

Due to the time limitation on this study the computer program provided by the Corps of Engineers for calculating navigation benefits was not operational until after the writing of this report. Thus no alternative estimates of navigation benefits are provided relaxing some assumptions deemed questionable. However, some guestimates are presented.

II. ANALYSIS OF THE IGLLB'S DATA BASE AND METHODOLOGY

The most important aspects of the navigation analysis are the IGLLB's estimates of commodities, the fleet characteristics, the route assumptions (including the number of shallow draft harbors), and the differences in lake levels due to changes in regulation. Because navigation is important to Wisconsin's economy and needs to be considered as an important factor in taking a position on any proposed operating rule for Lake Superior, it is necessary to analyze the IGLLB's data base with respect to Wisconsin's interests.

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* See RF Monograph 76-01, IES Working Paper 27, Hydrology.

A. Commercial Navigation in Wisconsin

In 1970 imports and exports from Great Lakes harbors were nearly equal—thirty-two and thirty million tons of cargo respectively. Imports through the Great Lakes were about one-fifth as large as imports through the United States seaports. Of the major bulk commodities considered, only grain is important in foreign trade. The cargoes for Wisconsin harbors are listed in Table 1.

Table 1 Imports-Exports, 1968

	IMPORTS		EXPORTS	
Harbor	$ Million	Million Net Tons	$ Million	Million Net Tons
Duluth-Superior	15.6	.20	293.6	6.93
Milwaukee	116.0	7.60	155.8	.85

Source: U.S. Department of Commerce 1970.

The 1970 and 1973 figures for Duluth-Superior suggest a slight decrease in imports and exports (Table 2).

Table 2 Duluth-Superior Tonnages, 1970 and 1973

	1970 (net tons)	1973 (net tons)
Canadian		
imports	58,501	193,617
exports	3,699,373	5,582,151
Other Foreign		
imports	56,511	103,618
exports	1,591,805	4,684,543
Domestic		
receipts	3,568,382	2,840,718
shipments	33,784,150	34,752,958
Total	42,758,965	48,158,190

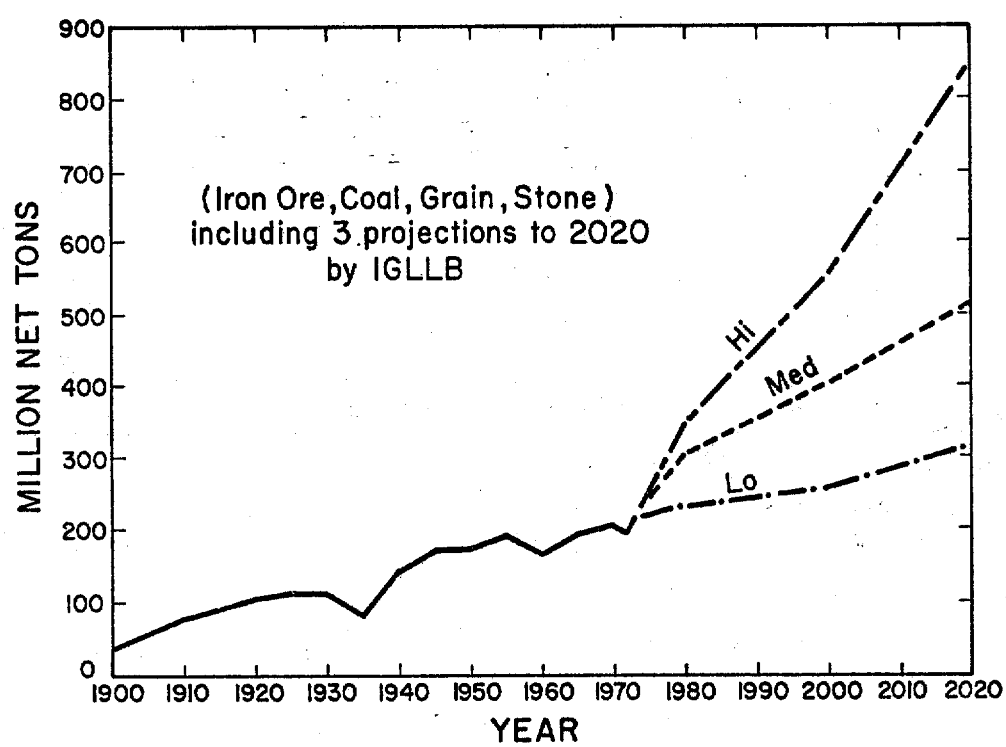
Source: U.S. Army Corps of Engineers 1970 and 1973.

The changes at Duluth-Superior are representative in direction, if not in magnitude, of the pattern on the Great Lakes as a whole, i.e., a gradual increase in trade with occasional downward fluctuations (Figure 1). At Duluth-Superior export tonnage dropped to 5.3 million in 1970 from 6.9 million in 1968; then the tonnage rose to 11.3 million in 1973 (Tables 1 and 2). Only Duluth-Superior and Milwaukee in Wisconsin have substantial amounts of foreign commerce. The marked increase in exports at the former harbor is due primarily to increased wheat shipments since 1970. Coal shipments at Port Washington and Oak Creek have dropped sharply, because railroads now transport more of the coal. In 1970 these two harbors, which are associated with power plants, received 27% of the coal that was shipped to Wisconsin harbors. Since plans have been approved to build large shipping facilities specifically for Western coal at Duluth-Superior, at a cost of about $30 million, this decrease in waterborne shipments will presumably be offset by new coal shipments from Lake Superior harbors, possibly as much as 20 million net tons per year.

The value of the iron ore shipped from Duluth-Superior in 1970 was about $310 million. The tonnage of grain, mostly wheat, was much smaller, but had the same value. The price of wheat has more than tripled since 1970, so grain shipments are by far the most valuable cargo from Wisconsin area harbors.

Coal, limestone, and cement are received at Wisconsin harbors and are important to Wisconsin commerce. The value of these three commodities when shipped was $34.8, $21, and $27 million respectively for 1970. Lime is used for cement, and in smaller amounts for agriculture and water treatment.

FIGURE 1 LAKE BULK FREIGHT COMMERCE BY YEARS, 1900-1973



A detailed description of the major commodities shipped from and received at Wisconsin harbors for 1970 is provided in attachment F.

There are eleven Wisconsin firms listed as shipbuilders and one additional firm as a manufacturer of dredges (Thomas Register 1970; Classified Directory of Wisconsin Manufacturers 1970). The firms and an approximate relative estimate of their dollar importance are given in Table 3.

TABLE 3 WISCONSIN SHIPBUILDERS

Listing	Location	Firm and Description	Classification*
Shipbuilders	Manitowoc	Burger Boat Company (yachts, cruisers)	AA
		Manitowoc Shipbuilding, Inc. (steel cargo, tugs, scows, dredges, car ferries, barges)	AAAA
		Manitowoc Co., Inc.	AAAA
	Marinette	Marinette Marine Corp. (steel ships and tugs)	AAAA
	Sturgeon Bay	Bay Shipbuilding Corp. (parent company, Manitowoc Co.)	AAA
		Palmer Johnson, Inc. (aluminum sail and power yachts)	AA
		Peterson Builders (fiberglass, steel, wood, aluminum)	AAA
	Superior	Superior-Lingerwood-Mundy Corp. (marine auxiliaries, steering gears, hoists, barge haul systems)	$500,000 (WMA)**
		Fraser Shipyards, Inc.	A
	Two Rivers	Schwartz Marine, Inc.	six employees (WMA)**
Dredges	Green Bay	Northwestern Engineering Co.	AAAA

Source: Thomas Register 1970.

*Classification Systems:

Approximate minimum tangible assets	Classification
over $1,000,000	AAAA
500,000	AAA
300,000	AA
100,000	A
50,000	B

**Classified Directory of Wisconsin Manufacturers 1970.

B. Commodities Distribution

The market distribution of the four major commodities, traffic patterns, and predictions of future commodity traffic on the Great Lakes are questionable as are any predictions of the future. Historically the four commodities, iron ore, coal, grain, and stone, have comprised approximately 85% of the total lake trade and have totaled about 200 million net tons a year for the last 10 years, a little over a third of which is due to iron ore. The IGLLB made low, medium, and high commodity projections for the years 1980, 1995, 2000, and 2020 from which it chose the medium value to use in its benefit calculations. The University Work Group analyzed the commodity growth rates for 1920-1970 and compared these to the IGLLB's medium projection for 1970-2202 (Table 4).

Table 4 Commodity Growth Rates (quantities in million net tons)

	ACTUAL				PREDICTED			
	1920*	1970**	Actual Growth 1920-1970	Growth*** Rate	2020**	Projected Growth 1970-2020	Growth*** Rate	1970-2020 Growth as % of 1920-1970 Growth
Iron Ore	58.5	81.9	23.4	.75%	221.0	139.1	2%	590%
Coal	26.4	49	22.6	1.25%	74	25	3/4%	110%
Grain	6.7	21.7	15.0	2.25%	38.9	17.2	1-1/8%	114%
Limestone	7.8	36.1	28.3	3%	103.8	67.7	2-1/4%	238%
Total	106.5	237	130.5	1.5%	515.5	278.5	1-1/2%	214%

* From Lake Carriers Assoc., Annual Reports
** IGLLB 1973, Appendix E
*** Compounded yearly

The most significant comparison is that of the compound growth rates for the 50-year periods 1920-1970 and 1970-2020. The projected rates of growth for the four commodities and total do not deviate greatly from the historical record except for the iron ore prediction, which constitutes the largest portion of the navigation benefits (IGLLB 1973, Appendix E, p. E-97).

The Levels Board recognized that their projections of commodity growth rates could vary by as much as 50% depending upon their assumptions (IGLLB 1973, Appendix E, p. E-121).

This potential for error is dampened because the IGLLB calculated benefits only for the bulk commodity traffic, disregarding the 15% of total traffic which is general overseas and other traffic.

The projections made for these commodities over a 50-year time span must be viewed cautiously because estimating future traffic patterns, commodities, and volume is difficult. Future commerce is always affected by the law of supply and demand which includes any new technologies which may develop, political decisions affecting imports and exports, intermodal competition, and worldwide socioeconomic changes. The energy crisis, for example, has encouraged development of the western coal fields, and a new coal dock is already under construction at Duluth-Superior to handle shipments of western coal. Such changes cannot be predicted but they will significantly alter future traffic patterns.

Different statistical techniques yield divergent findings for the estimates of future commodity traffic. Various statistical methods should be considered in order to get the full range of possible future commodity traffic patterns and resultant navigational benefits from regulation (Schenker 1975).

Figure 1 illustrates the commodity projections used in the study. A straight line projection of the historical trench suggests that the low projection rather than the medium projection might have been more appropriate. This would reduce the benefits by 29% (IGLLB 1973, Appendix E, p. E-122).

Thus, the traffic patterns for future commodity demand are uncertain with regard to the assumptions and method of estimation. Further analysis of Great Lakes commerce projections of the type now being completed by the Center for Great Lakes Studies at UW-Milwaukee are warranted.

C. Fleet Characteristics

The Great Lakes fleet which transports the bulk commodities is composed of two specific types of vessels referred to as dry bulk carriers and self unloaders. The IGLLB grouped vessels into ten classes by length which range from less than 400 feet to 1,000 feet (IGLLB 1973, Appendix E, p. E-44). Vessel carrying capacity varies from about 4,300 net tons average for a class 1 vessel up to a class 10 such as the Stewart J. Cort which has a 58,000 net ton capacity. Of the bulk trade vessels 57% are U.S. registered and the remainder are primarily Canadian. There are two constraints on the maximum size of vessels—those which traverse the St. Lawrence Seaway cannot exceed 730' x 75' while lakebound vessels are limited to 1,000' x 105' by the Poe Lock on the St. Marys River.

Based upon predictions given by the Lake Carriers Association the IGLLB projected the number of vessels by class which would be required through the year 2020. Although it is difficult to question the Lake Carriers Association's estimates, future vessel needs are closely related to commerce projections, and the benefits of regulation will generally accrue to the largest vessels since their drafts are often constrained by the Great Lakes controlling depths.

The IGLLB projects a gradual decrease in the size of the fleet by eliminating class 1-5 vessels, slightly decreasing the number of class 6 and 7 vessels, and estimating a large expansion within classes 8, 9, and 10 (IGLLB 1973, Appendix E, p. E-77-82). For example, it is predicted that the class 10 fleet will expand from none in 1970 to over 61 by 2020.

The IGLLB also assumed that all significant harbors for all commodity traffic would be deep-water harbors (27 foot depth or better) by 1995, and that the Welland Canal would be expanded to accommodate vessels up to 1000 feet in length and 105' in beam by 1995 (IGLLB 1973, Appendix E, p. E-45). It could very well be that this assumption underlies the large increase in class 10 vessels.

This assumption neglects the length of time (twenty years or more) between the proposal of a project of this magnitude and its actual authorization and construction.* Twenty years is an overly optimistic estimate of the completion date of such a project. Approval of an Environmental Impact Statement in the United States and the likelihood of extensive negotiations with Canada could prolong the planning period.

The actual expansion of the fleet from 1970 to 1975 does not even support the IGLLB's assumption. While many class 8, 9, and 10 vessels have been launched during this period, fleet expansion has occurred in every class (see Attachment A, Table 20). If this trend continues, the estimated benefits to navigation from the proposed regulation plans will decrease because the smaller vessels would continue to be used for trade between shallow draft harbors.

The size of new ships on order suggests that some of them are being designed with potential drafts which far exceed the controlling channel depths. Even if $2.1 billion were invested to increase the controlling depth of the channels to 31 or 32 feet this would not accommodate some of the ships on order which have potential drafts of up to 40 feet (Great Lakes Basin Commission 1975; see Attachment A).

D. Route Considerations

Channel and harbor depths, not the lake depths, are the major constraints to Great Lakes commercial navigation. At present the channel depth is maintained at a minimum of 27 feet below low water datum throughout the Great Lakes. Although channel depths restrict the maximum draft to which

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*H. Brockel 1975. Center for Great Lakes Study, University of Wisconsin—Milwaukee, July.

a vessel can load, various harbors place additional constraints on vessel drafts. Many of the harbors in the Great Lakes are shallow draft harbors (less than 27 feet) which limit the maximum draft of an inbound-outbound vessel utilizing the harbor. The docking facilities within the various harbors often have length limitations, which further restrict the vessel size. All of these factors must be considered when analyzing the various routes along the Great Lakes.

Rather than using actual routes between harbors shipping and receiving a commodity, the IGLLB developed average routes for a particular commodity. For grain there are two routes with Lake Superior as the origin and Lake Erie as the destination—the route for domestic shipments is 986 miles long while the route for import shipments is 864 miles long. How the IGLLB determined these average routes is unclear because there are five major grain harbors on Lake Erie.

Although Appendix E of the Levels Board report generally contains enough information to understand how the IGLLB calculated transportation costs, the report does not indicate how the total shipments on a route are broken down into imports, exports, and domestic transfers. This omission precludes analysis of the IGLLB's calculations. For example, one cannot determine how much grain is shipped on the import and export routes. The cost of a shipment on a route can be calculated and these are presented in Attachment E.

Another example of averaging in the IGLLB study is the "weighted average depth" used for evaluating the benefits that would accrue for the year 1970. These weighted average depths were determined by commodity for the various shallow draft harbors that shipped or received the major commodities on the Great Lakes. The depths are: iron ore—22.6', coal—21.4', limestone—23.8', and grain—21.6'. Presumably, the IGLLB calculated these weighted average depths by multiplying the cargo tonnage by the harbor depth and then dividing this by the total tons for each commodity for all the shallow depth harbors. It is not apparent why this weighted average depth was used because the shallow draft harbors for each commodity and the actual traffic routes between harbors are known. Thus, it is not clear what harbors constrain the shipment of the major commodities.

The total annual quantity of a commodity was divided among the applicable routes. For "current conditions" a percentage of this annual cargo was determined to be limited by shallow draft harbors. This procedure again points to the question of why the actual routes and quantities were not used—at least for the known conditions in 1970.

E. Lake Levels

Navigation depths are measured from a Low Water Datum (LWD). The frequency at which mean lake levels are below LWD under the various Lake Superior regulation plans is one indicator of the relative effect of these plans on navigation. Table 5 summarizes these frequencies for each lake during the navigation months based on the recorded data and the simulation of the various regulation plans. Plan SO-901 decreases the frequency of levels below LWD.

According to the IGLLB, levels on Lake Superior control approximately 75% of a plan's benefits to navigation:

> Some 50% of the total average annual benefits would be provided to the traffic route between Lakes Superior, Michigan-Huron, and Erie. An additional 26 percent would accrue to the traffic transversing Lakes Superior and Michigan-Huron . . . . Since the level of Lake Superior frequently controls the draft to which the ships using the lakes (emphasis added) can load, an upward relative adjustment in its levels . . . would provide direct benefits to the traffic involved. (IGLLB 1973, Appendix E, p. E-87)

Lake Superior tends to limit the loading of vessels to capacity 75% of the time since benefits from a plan occur only when a ship cannot load to capacity. Yet during the midsummer months (June, July, and August) Plan SO-901 creates two more occurrences of lake levels below LWD than does BOC, and the IGLLB estimates that over 50% of the commercial traffic occurs during these three months (Table 5) (IGLLB 1973, Appendix E, p. 76). Based on the occurrences of levels below LWD one wonders about the magnitude of navigation benefits. This uncertainty is quieted by the calculations of savings by route estimated in Attachment E of this paper. For instance, a uniform difference of .1 foot between two regulation plans over the navigation months could produce a savings or loss of about $170,000 on the iron ore traffic between Lakes Superior and Michigan. Small increases in Lake Levels when lake levels are low certainly can produce substantial benefits.

The IGLLB correctly concluded that Plans SO-901 Mod 7 and 8 will require some dredging of channels and harbors to prevent negative benefits to commercial navigation (Table 5). The extent and depth of the necessary dredging would require more extensive analysis than presented in the IGLLB report.

Another approach to examining the relationship between lake levels and navigation benefits is to calculate critical water levels, or that level below which ships cannot load to their full cargo capacity. Critical water levels are dependent on the ship's draft at its legal or design capacity, channel control depth, and a safety factor. The analysis of critical water levels in Attachment B indicates that no benefits to vessels of class 5 and below can be expected if the only constraint is the current navigation channel control depth of 27 feet. Only the larger ships can benefit from changes in lake level due to regulation when only the current navigation system is considered.

On the other hand, the shallower control depths in harbors create lower critical water levels, and the smaller ships do gain the opportunity for navigation benefits due to lake level regulation.

Table 5 Low Water Datum

Lake Superior*

Number of Monthly Mean Lake Levels Less than 600.0** with Supplies of 1900-1973

					SO-901	
	Beginning of Month Recorded Data*	BOC	SO-901	SEO-42P	Mod 7	Mod 8
April	40	45	39	40	50	60
May	26	19	21	22	43	48
June	7	7	11	12	32	38
July	6	5	5	6	26	33
August	3	4	2	4	24	29
September	2	4	0	1	24	28
October	2	4	1	2	25	32
November	3	4	5	5	31	35
TOTAL	89	92	74	92	255	303

Lake Michigan-Huron

Number of Monthly Mean Lake Levels Less than 576.8*** with supplies of 1900-1973

					SO-901	
	Beginning of Month Recorded Data*	BOC	SO-901	SEO-42P	Mod 7	Mod 8
April	13	11	12	12	11	9
May	12	10	5	7	4	3
June	7	7	4	5	2	1
July	4	5	4	5	1	1
August	3	6	5	5	1	1
September	10	9	4	7	3	3
October	10	12	9	11	5	4
November	12	14	13	14	10	10
TOTAL	70	74	56	66	37	32

Lake Erie

Number of Monthly Mean Lake Levels Less than 568.6*** with Supplies of 1900-1973

					SO-901	
	Beginning of Month Recorded Data*	BOC	SO-901	SEO-42P	Mod 7	Mod 8
April	5	0	0	0	-	-
May	5	0	0	0	-	-
June	4	0	0	0	-	-
July	4	0	0	0	-	-
August	4	0	0	0	-	-
September	5	0	0	0	-	-
October	12	1	0	0	-	-
November	24	2	1	1	-	-
TOTAL	63	3	1	1		

Lake Ontario

Number of Monthly Mean Lake Levels Less than 244.8*** with Supples of 1900-1973

	Beginning of Month Recorded Data*	BOC	SO-901	SEO-42P
April	48	36	38	39
May	27	14	14	14
June	21	6	6	8
July	26	6	5	8
August	29	8	7	11
September	42	36	41	41
October	52	66	68	70
November	57	73	74	74
TOTAL	302	245	253	265

*Frequencies are similar to those on p. 10 (North Central Division Corps of Engineering, Report on SEO-17P, so Sept. 1974) in consideration of effects due to rounding.

**Levels from IGLLB 1973, Appendix B, Vol. 2, for months August-December (1900-1972 data).

***Low Water Datums - Navigation season extends from April 1—November 30.

This raises the question that if the benefits to navigation from increased cargo carrying capacity for these smaller vessels is that important, why have the harbor channel depths not been increased? Actually the answer is not as simple as gaining additional cargo. The curvature of a river bend may be a limiting factor on ship length.

The importance of this critical water level analysis is that it clearly illustrates the role of larger vessels and shallow draft harbors as the major determinants of navigation benefits. A detailed analysis of shallow draft harbors is contained in Attachment D.

III. ANALYSIS OF THE IGLLB METHODOLOGY

The IGLLB's method of estimating the benefits to navigation is presented, the underlying assumptions critiqued, and alternative methods are discussed.

A. The IGLLB Method

The overall strategy for estimating navigation benefits was:

1. Estimate the amount of iron ore, coal, limestone, and grain to be shipped on the Great Lakes in 1970, 1995, and 2020.

2. Based on the lake levels simulated for the Basis of Comparison plan, calculate the total <u>average</u> annual shipping costs of these commodities for each of the three time periods.

3. Based on the lake levels simulated using an alternative regulation plan, calculate the total average annual shipping costs as in 2.

4. Subtract the total shipping costs under the alternative plan from those under the Basis of Comparison plan to obtain net beneftis in 1970, 1995, and 2020. Interpolate between these points to find the annual benefits for the intermediate years, and then calculate the equivalent annual cost at 7% interest.

The IGLLB performed the actual calculations of navigation impacts in the following manner:

1. For each commodity, country, and year:

   A. Estimate the quantity for 1970, 1995, and 2020 to be shipped from a lake of origin to a lake of destination. The 10 standardized routes were divided into three categories—imports, exports, and lakewise (US) or coastwise (C) (IGLLB 1973, Appendix E, pp. E-22, 66, 68-70).

2. For each of the eight navigation months:

   B. Multiply by the percent of annual shipments to be carried that month, independent of country, commodity, or year (IGLLB 1973, Appendix E, p. 76).

3. For each vessel class (dependent on commodity, country, and year) applicable under (1):

   C. Find the tonnage to be shipped by multiplying (2B) by the percent of total tonnage to be carried by vessels in this class (IGLLB 1973, Appendix E, pp. E-74-82).

4. For a year, use the simulated water levels for the given month to determine the tonnage which can be carried by a vessel in this class as follows:

   D. Find the minimum of the following:

      1. Water Level—Low Water Datum ± (channel depth or harbor depth whichever is smaller)

      2. Seasonal Load Line Limit

   E. IF the depth from (d) is greater than the vessel draft at capacity, the tonnage is equal to vessel capacity.

      IF NOT, subtract this depth from vessel draft at capacity and multiply by net tons per foot of immersion and subtract this from vessel capacity to obtain the tonnage carried on a trip for that month.

   F. Divide (C) by (E) to obtain the number of trips required for this vessel class for the month being considered.

   G. Multiply the number of trips by a round trip factor times the standardized distance for the route times the vessel speed to obtain travel time (IGLLB 1973, Appendix E, pp. E-72-73).

   H. Multiply the number of trips by the loading-unloading time per trip.

   I. Add (G) and (H). Multiply by the vessel operating cost per hours to obtain total transportation cost for this vessel and this water year (IGLLB 1973, Appendix E, pp. E-52-54).

5. Repeat 4 for each of the six simulated water years and average.

6. The sum over all vessel classes gives the total expected transportation cost for each month in (2) and for a commodity, country, and year. Sum over the months to obtain this annual total. Note these totals are also accumulated by route.

7. Repeating these calculations for 4 commodities, two countries, one obtains the total annual transportation cost for each of the years 1970, 1995, and 2020 and for each country.

In summary, to calculate an average annual navigation benefit from the use of Plan SO-901 instead of the pre-1973 plan for Lake Superior, the IGLLB estimated the demand for four commodities (iron ore, coal, grain, and limestone), the composition of the fleet by vessel size and characteristics, and the required routes. Then lake levels for each month and year were used to determine ship loadings which were used with estimated operating costs to estimate the total transportation costs for all commodities. Due to the self-imposed constraint that the cost-benefit analysis must cover a fifty-year planning horizon, the years 1970, 1995, and 2020 were selected as three distinct points in time where these various assumptions held. The total transportation costs were calculated for each of these three years under the appropriate assumptions under each of the SO-901 and Basis-of-Comparison plans based on simulated water levels. This resulted in the differences in total benefits shown in Figure 2.

These benefits in 1970 were \$616,200. They increased by \$461,700 in 1995 to the figure shown for 2020. Linear interpolation was used to obtain the benefit for intermediate years.

To calculate annual benefits the IGLLB projected the interpolation between 1995 and 2020 to the year 2022. The Levels Board then calculated the present worth of the years 1973-2022 in 1972 and calculated the uniform equivalent annual benefit over the period 1972-2022.

B. Alternative Benefit Calculation Method of the University Work Group

Based on averages and estimates as discussed above the benefits calculated were labelled to occur in 1970, 1995, and 2020. Since even the labelled 1970 benefits only marginally reflect actual 1970 data there seems to be an equally good argument to label these three points in time 1972, 1997, and 2022. In which case one would use the alternative method of calculating the equivalent annual benefit as shown in Figure 2. To calculate annual costs, one would use the interval shown between the three points in time to obtain a total present worth in 1972 and then obtain an equivalent annual cost over a fifty-year period between 1972 and 2022 as an estimate of the annual benefits. If this approach had been used, there would have been about \$40,000 less annual benefits.

As an example of the IGLLB's use of estimates in the benefit calculations, the IGLLB assumed that the fleet carried a certain percentage of the total annual cargo in each navigation month. These percentages were assumed not to vary between commodities or over time. The percentages were (IGLLB 1973, Appendix E, p. E-76):

April	10%	June	17%	Aug.	17%	Oct.	10%
May	11%	July	17%	Sept.	10%	Nov.	9%

FIGURE 2 NAVIGATION ANNUAL BENEFIT CALCULATIONS

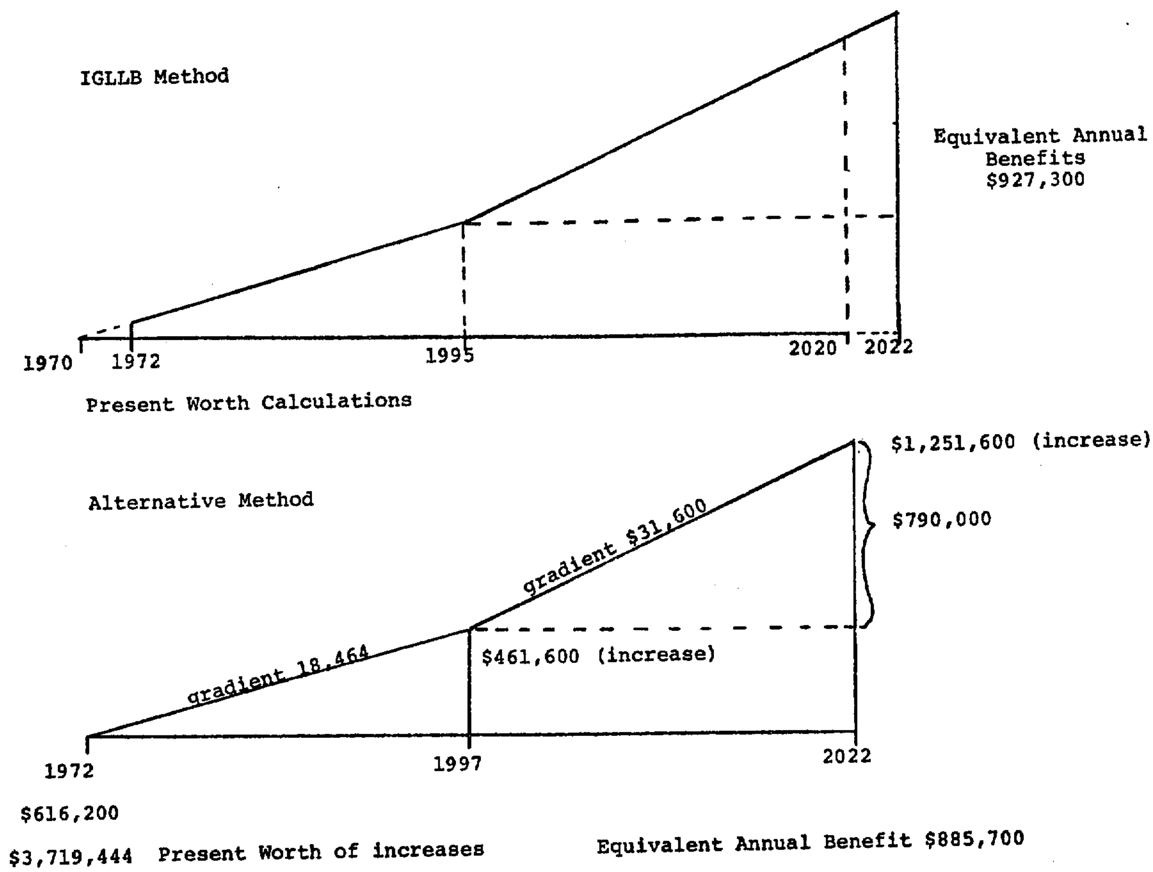

Table 6 shows how these percentages actually varied with commodity and time for selected years.

An examination of the actual data for coal traffic in 1970 shows a flatter distribution over the navigation months than the distribution used in the benefit calculations. Comparing the columns of Table 6 one can conclude the distribution by month not only varies between commodities but also year to year.

As a second example of the 1970 assumptions Greenwood (1970) indicates there are twelve class 7 vessels with average maximum capacity of 25,100 net tons and average draft of 27.6 feet. The IGLLB, however, indicated only nine vessels, overestimated the capacity at 27,200 tons, and underestimated the draft by .1 foot (IGLLB 1973, Appendix E, p. E-77). These examples suggest that the alternative method of calculating the benefits is as valid a method as that used by the IGLLB. They tend to contradict the IGLLB's statement that: "Actual commerce and fleet composition were utilized for evaluation of year 1970." (IGLLB 1973, Appendix E, p. E-65).

TABLE 6 COMMODITY DISTRIBUTION BY MONTH

	IRON percentages			COAL From Lake Erie			COAL From Lake Michigan		GRAIN		
	1970	1971	1972	1970	1971	1972	1971	1972	1972	Welland Canal	St. L. Seaway
Jan.		.57	.66								
Feb.				1.78	2.82	2.82	1.96				
Mar.	.04										
April	7.35	6.26	3.54	11.47	10.55	8.62	12.02	9.52	3.20	5.56	5.14
May	13.14	14.61	12.75	12.89	14.40	12.39	16.83	13.44	12.58	12.08	12.03
June	13.66	15.47	12.83	12.03	14.04	12.63	17.27	13.76	13.06	12.33	12.42
July	14.54	15.66	13.46	9.83	12.20	10.84	8.84	11.80	12.48	12.07	12.83
Aug.	14.40	11.89	13.85	11.55	14.45	12.29	18.52	15.62	13.93	12.55	12.86
Sept.	13.28	12.24	12.82	11.66	13.44	12.10	15.35	12.15	10.92	12.69	12.57
Oct.	11.50	11.42	12.07	12.36	7.17	12.18	3.63	12.10	12.07	14.24	14.52
Nov.	8.39	8.30	10.73	10.34	4.25	11.69	2.32	9.28	12.41	12.95	13.35
Dec.	3.70	3.58	7.29	6.08	6.67	4.46	3.25	2.31	9.35	5.54	4.28
	100.00%	100.00%	100.00%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total	73568000	66283406	70148090	42609504	37731310	38000979	5195328	5540072			
	GROSS	TONS		NET	TONS		NET	TONS			

Source: Lake Carriers Association, Annual Report 1972.

C. VESSEL SIZE

One of the major factors in the significant increase of benefits in 1995 and 2020 is the assumption that vessel size will significantly increase by these years. While this assumption is not necessarily incorrect, it must be emphasized that it does have an extreme impact on the benefit calculations.

There are underlying assumptions which allow for the better utilization of larger vessels in future years which include the assumption that all harbors will be dredged to 27-foot depths below low water datum by these points in time and that certain locks will be improved to handle the larger vessels. The assumptions for 1970 include a percentage of harbors which do not in fact have the 27-foot depth capability at present.

As indicated in Attachment D, to improve these shallow draft harbors and docking facilities to accommodate these larger vessels will be costly. The assumption of increasing vessel size presumes that the cost-benefit analyses for harbor improvements will prove the investment worthwhile. If these studies do not justify the harbor improvements, then one would not expect these increases in vessel size. This in turn would reduce the benefits to commercial navigation due to regulation.

Based on economic theory one would expect that ship owners would move toward larger vessels to reduce unit transportation costs. As indicated in Attachment E of this study the data used in the IGLLB study conforms to economic theory as do the results of the computer benefit calculations shown in Table 7.

From Table 7 it is evident that, with one exception, the decreasing unit cost holds as expected. However, for grain between 1995 and 2020 there is an increase in the unit costs per ton despite the increase in larger vessels. The reason for this discrepancy is not known at this time.

Thus, it is clear that if the public will support harbor improvements the size of vessels will increase significantly. The question is whether or not the public will provide the support.

TABLE 7 TOTAL TRANSPORTATION COSTS PER TON (PLAN SO-901)

U.S.	1970	1995	2020
Iron Ore	2.084	1.346	1.237
Coal	.792	.702	.598
Limestone	.995	.642	.556
Grain	3.246	1.272	1.838

Source: IGLLB 1973, Appendix E, E-109-112.

There is no question that the pressure to reduce unit transportation cost will tend to increase the size of vessels operating on the Great Lakes. In fact, Attachment A documents the increase in average vessel size between 1970 and 1975 for class 7 vessels. The major issue is the rate of increase. Unfortunately, the University Work Group did not have time to measure the effect of increasing vessel size on navigation benefits.

The Work Group did estimate the time distribution of navigation benefits and their relative magnitudes. The estimation is in terms of tenths of a foot of additional draft available for cargo carrying due to differences in water levels. The assumptions used by the IGLLB were followed. For instance, in July, a class 7 vessel can load to maximum draft. The critical water level below which it cannot load to maximum draft is given by: low water datum minus channel depth plus maximum vessel draft plus squat or safety factor. For a class 7 vessel on Lake Superior this is: 600 - 27 + 27.5 + 1.5 = 602. Under these assumptions a class 7 or larger vessel cannot load to capacity during any summer month under either regulation plan, since 602 feet is the maximum elevation allowed. This suggests that the assumptions ought to be viewed with suspicion because these ships often do load to capacity.

If the simulation of water levels indicates a level below the critical water level for either Plan SO-901 or BOC, or both, then a class 7 vessel can use additional draft for cargo under one of the plans. The amount measured in feet of draft, is the difference between the lowest level and either the critical water level or the higher water level—depending on which is lower. The convention used in Tables 8-10 is that a positive number indicates additional loading capacity under Plan SO-901 (SO-901 is beneficial to navigation). A negative number indicates additional loading capacity under the BOC plan (SO-901 is detrimental to navigation).

Table 8 indicates that Plan SO-901 alternates between being beneficial and detrimental to navigation for a class 7 vessel. The maximum benefit is .8 feet and the maximum decrement is 1.0 feet. While Plan SO-901 would have been beneficial during the extreme low supply period of 1920-1926, it would have been detrimental for the entire decade 1933-43. The average for each month does show a small benefit.

In Table 9, this same analysis for a class 6 vessel is presented. Comparing Tables 8 and 9 the relatively small number of occurrences of benefits under either plan clearly indicates that the larger vessels create most of the benefits due to differences in lake levels caused by regulation.

For a selected number of years in which Plan SO-901 was beneficial to navigation on Lake Superior, the same type of critical water levels analysis was made on Lakes Michigan-Huron for a class 6 vessel (Table 10). It would appear that for at least fourteen years the potential benefits to navigation could not be realized because of the detriment to navigation on Lakes Michigan-Huron. This is because a ship route traversing Lake Superior and Michigan-Huron is limited by the water level on either lake system.

While the above analysis is admittedly crude and incomplete, it does raise serious questions about the averaging calculations performed in the IGLLB's Navigation Benefits computer program. The University analysis, using the same calculations, the same assumptions, and the same data casts some doubt on the frequency and magnitude of navigation benefits which warrants further analysis and explanation. This is especially warranted since the IGLLB attributed 76% of the navigation benefits to routes using Lake Superior and Michigan-Huron. (IGLLB 1973, Appendix E, E-87).

D. Fixed Charges

It is extremely unlikely that the change in water levels due to the acceptance of any regulation plan will affect the size and composition of the commercial navigation fleet. The IGLLB at least implicitly recognizes this:

> Any increase or decrease in lake levels resulting from natural or man-made causes will change the cargo-carrying capacity *of the fleet* to some degree.

TABLE 8 ADDITIONAL (+) IRON ORE CARGO LOADED UNDER PLAN SO-901 COMPARED TO BOC FOR A CLASS 7 VESSEL ON LAKE SUPERIOR (IN TENTHS OF A FOOT OF DRAFT)

Iron Ore
Class 7 Vessel Lake Superior

Critical Level	April 600.3	May 601.2	June 602	July 602	Aug. 602	Sept. 601.2	Oct. 600.3	Nov. 600.2	Dec. 600.2
1900									
1901				.1	.1	.2			
1902	.2	.3	.1	.2	.1	.2	.2	.2	.1
1903	.1	.2	.2		.1	.1			
1904	.3	.3	.3	.4	.4	.2			
1905	.2	.3	.2	.3	.3				
1906	.2	.4	.4	.4	.3	.4			
1907	.3	.2	.2	.2	.3	.2			
1908	.4	.5	.5	.4	.4	.3			.1
1909	.3	.4	.4	.3	.3	.2			
1910	.1	.1	.1		.2	.2		.1	.2
1911	.2	.3	.2	.2	.2				
1912	-.1	-.1	.1	-.1	-.1				
1913	.3	.4	.4	.3	.3	.1			
1914	.2	.2	.2	.2	.2	.2			
1915	.2	.3	.2	.1					
1916	-.1	-.1	-.1	-.2	-.1				
1917			.2	.3	.5	.2			
1918	.7	.8	.7	.7	.7	.4			
1919	.2	.5	.5	.6	.6	.6			
1920	.1	.4	.3	.3	.3	.3			
1921	.5	.4	.4	.3	.4	.3		.1	.3
1922	.4	.3	.4	.3	.4			.2	.4
1923	.3	.4	.4	.5	.4	.4	.5	.5	.5
1924	.4	.5	.5	.5	.5	.5	.5	.5	.5
1925	.5	.5	.5	.6	.5	.5	.5	.4	.4
1926	.4	.5	.5	.4	.5	.5	.4	.3	.2
1927		-.2	-.2	-.3	-.3	-.3	-.1	-.2	-1
1928	-.1	-.1	-.1	-.1					
1929	.1	.2	.4	.6	.7	.5			
1930	.6	.8	.8	.7	.5	.5			
1931	.4	.3	.3	.3	.4	.3	.2		.1
1932			-.1	-.2	-.2	-.3	-.2	-.3	-.3
1933	-.3	-.3	-.4	-.4	-.3	-.3		-.1	-.4
1934	-.6	-.6	-.7	-.7	-.7	-.7			-.1
1935	-.7	-.8	-.8	-.7	-.8	-.6			-.2
1936	-.6	-.7	-.7	-.7	-.7	-.6	-.2	-.3	-.5
1937	-.6	-.6	-.6	-.7	-.7	-.6	-.1	-.1	-.3
1938	-.5	-.4	-.4	-.4	-.4	-.4			
1939	-.4	-.4	-.4	-.4	-.4	-.4			-.1
1940	-.1	-.2	-.2	-.3	-.3	-.3	-.1	-.1	-.2
1941	-.2	-.2	-.3	-.4	-.4	-.4			
1942	-.3	-.3	-.4	-.2	-.2	-.2			
1943	-.1	-.1		-.1	-.1	.1			
1944	.4	.4	.4	.2	.2	.2			
1945		.1			.1	.2			
1946	.1	.2	.2	.2	.2	.1			
1947					.1	.2			
1948	.3	.3	.3	.3	.2	.2			
1949			-.1	-.2	-.2	-.2			-.2
1950	-.4	-.3	-.4	-.4	-.4	-.2			
1951	-.3	-.3	-.3	-.3	-.3				
1952	-.1		.1	.3	.3	.4			
1953	.3	.5	.5	.4	.4	.1			
1954	.3	.4	.3	.3	.2	.3			
1955	.5	.6	.5	.5	.5	.5			
1956	.1	.2	.1	.2	.1	.1			
1957		-.1	-.1	-.2	-.1	-.1			
1958	-.1	-.1	-.1	-.1	-.2	-.3	-.1	-.1	-.4
1959	-.5	-.4	-.4	-.5	-.5	-.5			-.2
1960	-.3	-.3	-.3	-.1		.1			
1961									
1962				-.1	-.1	-.1		-.1	-.2
1963	-.4	-.4	-.5	-.5	-.6	-.2	-.3	-.3	-.2
1964	-.6	-.7	-.8	-.8	-.8	-.9	-.3	-.4	-.6
1965	-1.0	-1.0	-1.0	-1.0	-.9	-.9			
1966	-.5	-.9	-.7	-.7	-.5	-.4			
1967	-.5	-.5	-.5	-.4	-.3	-.3			
1968			-.1	-.2	-.2				
1969	-.2	-.2	-.2	-.1		.2			
1970	.3	.2	.2	.1	.1	.1			
1971		.2	.3	.3	.2	.1			
1972		.3	.3	.4	.4				
Total	-.1	2.5	1.9	.8	1.8	.9	.9	.3	-1.2
Average	~0	.03	.03	.01	.03	.01	.01	~0	-.02

Number of years Plan SO-901 beneficial to navigation* 39
Number of years Plan SO-901 detrimental to navigation 31

*This does not take into account any limitations on navigation due to other lakes.

TABLE 9 ADDITIONAL (+) IRON ORE CARGO LOADED UNDER PLAN SO-901 COMPARED TO BOC FOR A CLASS 6 VESSEL ON LAKE SUPERIOR (IN TENTHS OF A FOOT OF DRAFT)

Level at which no cargo lost	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	598.5	599.4	600	600	600	599.4	598.5	598.1	598.1
1911			.1						
1923		.1	.4	.4	.2				
1924		.4	.6	.5	.5				
1925		.5	.5	.6	.5				
1926	.1	.5	.5	.4	.5				
1958			-.1						
1963			-.2						
1964			-.1						

TABLE 10 ADDITIONAL (+) IRON ORE CARGO LOADED UNDER PLAN SO-901 COMPARED TO BOC FOR A CLASS 6 VESSEL ON LAKE MICHIGAN (IN TENTHS OF A FOOT OF DRAFT)

	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Critical Level	577.1	578.0	578.8	578.8	578.8	578.0	577.1	577.0	577.0
1908									
1918									
1923		-.1	-.6	-.6	-.6	-.1			
1924		-.5	-.7	-.6	-.7	-.1			-.2
1925	-.4	-.7	-.6	-.6	-.7	-.6	-.6	-.6	-.6
1926	-.6	-.6	-.6	-.6	-.6	-.4	-.5	-.4	-.3
1930									
1934	-.2	-.2	-.2	-.1	-.2	-.2	-.2	-.2	-.2
1935	-.2	-.2	-.2	-.3	-.3	-.3	-.4	-.5	-.4
1936	-.3	-.4	-.4	-.4	-.4	-.5	-.2	-.5	-.5
1937	-.5	-.5	-.4	-.4	-.4	-.5	-.3	-.4	-.5
1955									
1959	-.3	-.3	-.3	-.3	-.3	-.3			
1963	-.4	-.4	-.3	-.3	-.3	-.3	-.3	-.4	-.4
1964	-.3	-.3	-.3	-.2	-.2	-.1	-.1	-.1	-.2
1965	-.2	-.3	-.3	-.2	-.3	-.4	-.2	-.2	-.2
1966		-.4	-.5	-.5	-.6	-.7	-.3	-.3	-.2
1967		-.2	-.6	-.5	-.6	-.1			

> To the extent that the cargo-carrying capacity of *the* prospective *fleet* is increased, by regulatory measures or natural causes, the volume of the commodities available for shipment can be carried in fewer trips . . . (IGLLB 1973, Appendix E, E-78-79, emphasis added).

The size and composition of the fleet is affected primarily by the volume of cargo to be shipped, general perceptions of the economic climate, and the prospect of channel and harbor improvements. It is hard to believe that the decision on whether or not to build a new ship will recognize the small differences in water levels due to regulation.

Thus, the fixed charges of ship amortization, interest, and company overhead are *not relevant* in calculating the benefits to navigation from regulation of Great Lakes water levels. Consider a simple example. Suppose on a particular route for 1972, Plan SO-901 would save one trip for some vessel class and commodity and using typical operating costs the savings might be $200,000 (IGLLB 1973, Appendix E, p. E-54). This would include about $80,000 in fixed charges. These charges, however, are on an annual basis so that company overhead and ship amortization will be charged off on the company's profit and loss statement regardless of whether or not the trip was made. The only *realized* transportation cost savings is the variable operating costs, $120,000.

It is true that the firm's prices for transportation in 1972 were based on estimates to recapture this fixed cost and that the imbalance created by the saving of one trip could affect future prices. However, this effect is so embedded in the company's total financial situation that it is not calculable.

In order to estimate the true benefits to navigation a detailed breakdown of operating costs for all vessel classes was obtained from the IGLLB (Table 11).*

The ratios of operating costs to total costs for each vessel class were averaged by the percent of cargo, by commodity, carried by each vessel class. This provides a weighted ratio of variable to total operating cost which would be applicable to the benefits shown by the Levels Board (IGLLB 1973, Appendix E, Table E-43, p. E-95). These ratios are given in Table 12. When applied to the IGLLB estimates one obtains the benefits estimates shown in Table 13 which includes interpolation to 1972 and extrapolation to 2022 estimates.

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*The only accurate method of obtaining benefit data comparable to the IGLLB data (IGLLB 1973, Appendix E, p. E-95) would be to rerun the navigation benefit computer program using variable instead of total operating costs. However, this was not possible due to the shortness of the study period and the time at which the program was operational.

Table 11 Vessel Fixed and Variable Operating Costs — 1972 Dollar

(1) Class	(2) Daily Fixed	(3) Daily (Variable) Operating	(4) Total	(5) Per hour	(6) Ratio: (Variable) Operating to Total	(7) Variable Operating per Hour
2	$1,854	$3,451	$ 5,305	$221	.651	$144
3	$2,196	$3,845	$ 6,041	$252	.636	$160
4	$2,560	$4,564	$ 7,124	$297	.641	$190
5	$3,028	$4,861	$ 7,889	$328	.616	$202
6	$3,290	$5,063	$ 8,353	$348	.606	$211
7	$3,566	$5,223	$ 8,789	$366	.594	$218
8	$4,652	$6,886	$11,538	$481	.597	$287
9	$4,894	$7,418	$12,312	$513	.603	$309
10	$5,700	$8,544	$14,244	$594	.600	$356
*7	$2,660	$3,489	$ 6,149	$260	.567	(1967 Cost Estimate)

Sources: Columns 2—5 data supplied by IGLLB; columns 6 and 7 calculated by the University Work Group.

Table 12 Ratio of Variable Operating Cost to Total Operating Cost Weighted by Percentage of Cargo Carried by Vessel Class

	U.S. Fleet			Canadian Fleet*		
	1970	1995	2020	1970	1995	2020
Iron Ore	.614	.603	.600	.602	.594	.597
Coal	.627	.614	.599	.599	.610	.597
Limestone	.626	.611	.599	.607	.614	.597
Grain	.626	.605	.599	.603	.599	.599

Source: IGLLB 1973, Appendix E, Tables E-33—E-38, pp. E-77—82.

*Based on U.S. vessel data (Table 13).

TABLE 13 NAVIGATION BENEFITS FOR PLAN SO-901 BASED ONLY ON VARIABLE OPERATING COSTS

U.S. Fleet	1970	1972	1995	2020	2022
Iron Ore	$191,875	$214,002	$468,471	$816,480	$844,320
Coal	24,390	22,439	0	15,514	16,755
Limestone	22,724	22,909	31,955	70,383	73,457
Grain	28,608	26,876	6,958	22,882	24,156
	267,597	286,226	507,384	925,259	958,688
Canadian Fleet					
Iron Ore	26,669	28,584	50,609	66,028	67,262
Coal	17,012	16,432	9,760	10,567	10,632
Limestone	1,578	1,722	3,377	5,731	5,919
Grain	68,823	69,566	78,110	112,313	115,049
	114,082	116,304	141,856	194,639	198,826
Total	$381,679	$402,530	$649,240	$194,639	$198,826
Table 43*	$616,200		$1,077,800		$1,867,800

*IGLLB 1973, Appendix E, p. 95.

One note of caution is necessary in interpretating Table 13. The Canadian operating cost data were not presented in detail as was the U.S. data. Thus, two assumptions underlie the University Work Group's calculations.

A. The Canadian cost estimates include fixed charges and that the ratio of variable to total operating cost for a vessel in a particular class is the same as for a U.S. vessel.

B. The Canadian cost estimates reflect only variable operating costs.

The calculations in Tables 12 and 13 incorporate assumption A which is admittedly quite risky.

Table 14 summarizes the equivalent annual benefit under both assumptions, calculated both by the IGLLB method and the previously suggested alternative method. The exclusion of fixed charges reduces the benefit estimates significantly, between $275,000 and $390,000. This is approximately a 30-42% reduction in benefits.

TABLE 14 SUMMARY—NAVIGATION ANNUAL BENEFITS

	Total Cost: IGLLB Method	Total Cost: 1970-2020 Estimator	Variable Cost: IGLLB Method A	Variable Cost: IGLLB Method B	Variable Cost: 1970-2020 Estimator A	Variable Cost: 1970-2020 Estimator B
U.S. Fleet						
Iron Ore	$609,800	$570,978	$368,972		$345,839	
Coal	19,500	21,737	12,196		13,585	
Limestone	49,900	47,910	30,621		29,471	
Grain	29,000	30,846	17,934		19,146	
U.S. Total	708,200	671,471	429,723	429,723	409,041	408,041
Canadian Fleet						
Iron Ore	68,600	65,503	40,908		39,113	
Coal	21,700	22,536	13,104	can	13,571	can
Limestone	4,500	4,241	2.737	est.	2,585	est.
Grain	124,300	121,944	74,626		73,268	
Can. Total	219,100	214,224	131,375	219,100	128,537	219,100
Total	$927,300	$885,695	$561,098	$648,823	$536,578	$627,141
Difference		-$ 41,600	-$366,200	-$278,500	-$390,700	-$300,200

E. RANDOM ASSIGNMENT OF VESSELS TO ROUTES

The IGLLB assumed that every ship in the fleet would be equally likely to be utilized for each route. This randomness of ship use simply is not the case. The ship owners know the various routes that their vessels will take in transporting the various commodities, and know the constraints that are imposed by the harbors and navigation system along these routes. Since these owners wish to maximize their profits, they will attempt to utilize their ships to their fullest potential. The chance that a deep-draft vessel would service a shallow draft harbor and thus be greatly under-utilized is very remote. A prime example can be found in the case of iron ore shipments. The 1,000 foot vessels now in service traverse established routes that utilize only deep-water harbors—harbors in which the maximum utilization of these vessels can be obtained.

The randomness of route assignment is not a purposeful assumption but arises from the design of the computer program and the way in which the input data was organized. The Work Group's analysis of the computer program and the input data indicates that the benefits are calculated for each country using a single commodity and year and a *single* harbor depth. The harbor depth for shallow draft harbors is averaged by commodity over all harbors in the Great Lakes (IGLLB 1973, Appendix E, Table E-21, p. E-67). The percentages of 1970 traffic at shallow draft harbors by origin and destination, commodity, and country were then used to find the tons of a particular commodity to be shipped to shallow draft harbors on each route (IGLLB 1973, Appendix E, p. E-114).

These tonnages along with the shallow draft harbor depth are primary inputs for each computer run. This tonnage to be shipped is then assigned to a vessel class according to the distribution of annual commodity tonnage by fleet and classes of vessel (IGLLB 1973, Appendix E, E-74-75). For instance, 11% of the iron ore in 1970 is assigned to class 7 vessels. If, as is logical, class 7 vessels primarily operate out of 27-foot channel harbors and the smaller vessels service the shallow draft harbors, then this assignment inflates the benefit calculations.

This random effect is created by neglecting the interrelationships between vessel size, route and harbor. The simplification is unimportant when all harbors are assumed to have 27-foot depth, but inflates the benefits for shallow draft harbors. The IGLLB does state computer runs for 1970 were made under both assumptions. However, we assume that the $616,200 benefit for 1970 is based on shallow draft harbors, because there appears to be no other reason for elaborating on the subject (IGLLB 1973, Appendix E, p. E-94).

As a corollary to this randomness assumption, the IGLLB never identified the various shipping routes for the various commodities being transported by harbor. Instead, the Levels Board merely identified the various amounts of commodities that flowed between the various lakes. Thus, there is no way of determining whether the weighted average depth calculations for the shallow draft harbors are reasonable.

It is apparent that more study is warranted in the area of shipping routes of the various commodities. Rather than a weighted average, actual shallow draft harbors should be identified. The various routes should be identified to determine just where the constraints are within the Great Lakes Navigation system.

F. Effect of Implementing Plan SO-901

The Work Group interpreted the 1970 benefits to mean the benefits which occur in the first year Plan SO-901 is implemented, which was 1973. The accuracy of estimation for this initial year is more important than the estimates for 1995 or 2020 since the calculation of equivalent annual benefit places the greatest weight on the near future and smallest weight on the distant future. The overestimation due to shallow draft harbors and the random assignment of vessels to routes could be significant since this assumption only inflates the estimate for the initial year.

Another source of possible overestimation is the averaging of transportation costs based on the differing water levels over the period 1900-1967. The realization of the benefits would most likely occur if the plan were implemented in a year with average water levels. It is risky to generalize what might happen to the benefit estimate if the plan were implemented in a period of low water. The initial benefits would be much lower upon implementation during a high water period because the number of times vessels are not loaded to capacity would be significantly reduced under any regulation plan. Since Plan SO-901 was implemented in a high water period, $616,200 is probably a significant overestimate of the benefit for the last several years.

In defense of the IGLLB, it would have been a monumental task to relate the first year's benefits to current water levels. The method selected by the IGLLB to evaluate navigation benefits is not adapted to this kind of analysis and a completely different approach would be required. Probably the time and money constraints made a more realistic simulation model of Great Lakes navigation infeasible.

CONCLUSIONS

Navigation benefits are *real*. Small differences in lake levels cause large differences in transportation costs.

Navigation is important to Wisconsin and should be considered equally with other interests in developing state policy.

Lake Superior appears to be a critical factor with respect to navigational interests and has been regulated to preserve them since the beginning of regulation.

Based on the historical supply to the basin the simulations of lake levels show that Plan SO-901 is beneficial to navigation during some time periods and not detrimental during other periods. For instance, on Lake Superior during the historical record 1900-1972, Plan SO-901 would have been beneficial 39 months and detrimental 31 months.

The strategy of the method used by the IGLLB to calculate navigation benefits is sound, but the tactical assumptions and data used in carrying out the calculations are sufficiently controversial to warrant skeptical interpretation of the numerical results.

Navigational benefits from Plan SO-901 are overstated and are likely to be in a range of one-third to two-thirds the value estimated by the IGLLB. The primary reasons are:

1. The inclusion of fixed operating costs when these are not direct savings in transportation costs.

2. The method selected to calculate equivalent annual benefits.

3. The routing of large draft vessels to shallow draft harbors.

4. The implementation of Plan SO-901 during a high water period.

The increasing size and draft of cargo vessels is a primary determinant of navigation benefits due to regulation of water levels. Lock size is the primary constraint on vessel size; dock capacity and location, as well as harbor and channel depths are also limiting factors. Change in water levels due to regulation is probably a negligible factor with respect to the determination of vessel size.

ATTACHMENT A

GREAT LAKES LOAD LINE LIMITS AND OTHER NAVIGATION VARIABLES

S. Thompson

INTRODUCTION

Approximately 40% or $927,000 of the total average annual benefits ($2,370,000) which the Levels Board postulates will accrue to the Great Lakes from Plan SO-901 is due to benefits to commercial navigation. This paper discusses some of the constraints involved, including load line limits, past and present, possibility of future draft increases, shipping season lengths, comparison of ship registrations, commerce projections, and fuel consumption. A number of inconsistencies occur between the IGLLB report and other informational sources which suggests that reanalysis of the navigation benefits from Plan SO-901 be contemplated.

LOAD LINE LIMITS

Load line limits have a significant effect on the percentage of capacity to which Great Lakes bulk freighters, self unloaders and other ships may be loaded. The limits are imposed by each vessel's assigning authority and are precisely stipulated for each of the navigation seasons. The actual assigned draft limitations reflect each ship's maximum draft (depth) available, relative seaway water levels, seasonal variations in weather, quality of ship construction, and seaway controlling depths.*

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* U.S. Coast Guard Regulations state in part that:
45.01-1(a) Load lines are established for merchant vessels of 150 gross tons or over when engaged on Great Lakes voyages in Conformity with the Coastwise Load Line Act, 1935, as amended (46 U.S.C. 88-88i).
(No merchant vessel over 150 gross tons shall be allowed to proceed on a voyage unless such vessel is:)
45.01-10(a)(1) Marked with load lines under the load line regulations in Part 42 or 43 of this subchapter and has on board a valid load line certificate, or
45.01-75(c) No vessel shall be loaded so as to submerge at any time the load line applicable to the season (U.S. Coast Guard 1971).

Load line limits constantly change and evolve, reflecting changing technology and environment. Table 15 illustrates the change in limits which have regulated the loading of a typical class 7 vessel, the George M. Humphrey, a 710-foot bulk freighter built in 1954.

In fifteen years the allowed drafts increased substantially: midsummer—from 26'7" to 27'9", a change of 14"; summer—from 25'11" to 27'1", also a change of 14"; intermediate—from 24'11½" to 27' 1", a change of 25½"; winter—from 23'9" to 26'9½", a change of 36½". The increase in legal drafts meant an increase in midsummer carrying capacity from 24,900 tons to 26,400 tons. While not all of the 36½" increase in winter drafts is explainable, 12" of the winter draft increase is due to a 1971 law which added about one foot in draft to 37 class 5, 6, and 7 vessels which were constructed after 1948. The modification recognized the use of higher strength steel in ship construction.

Although not as impressive as the Humphrey example in terms of amount of load line change, comparison of average seasonal load lines for an entire class of ships shows comparable results (Table 16).

The IGLLB figures for the maximum (midsummer) draft for class 7 vessels at capacity differ from those in Table 16. The differences are small but are probably significant in light of the actual changes in lake levels expected with the institution of Plan SO-901 (Table 17).

The load line limits partly respond to changing lake levels. Consider the George M. Humphrey as a specific example. Mean lake levels on Lake Superior rose over the period 1964-1974 from 600.3 to 601.28, a change of 0.98 feet. The midsummer load line limits mirrored this change by being increased 1'7" during the same period. The more spectacular load line limit increases for the intermediate and winter seasons reflect more than the change in water levels and, keeping in mind the tremendous loading potential per inch of additional draft, tend to minimize the relative importance of the proposed regulatory plans. Of course, one might also interpret the situation as one in which shipowners considered the limits of 10 years ago as being overcautious and succeeded in convincing the Coast Guard that the ability to transport more cargo was worth the additional risk.

Future Drafts and Controlling Depths

Allowable load line draft limits will steadily increase. The Shore Captains Committee of the Lake Carriers Association in 1971 concluded "that a long-term recommendation for deepening the connecting channels should be presented to the Corps of Engineers at the appropriate opportunity and that such recommendation should propose a uniform depth of 32 feet."

Analysis of the physical dimensions of new lake vessels under construction or on order supports the deeper channel and draft contention (Table 18). The most interesting information is contained in the column on proposed depth dimension. Statistics for the Great Lakes' largest current vessels have been added for comparison. They are the Roger Blough and the Stewart Cort.

TABLE 15 HISTORY OF LOAD LINE LIMIT CHANGES; GEORGE M. HUMPHREY

Year	Draft: MidSummer	Sum	Int	Win	MS Cap
1961	26'7"	25'11"	24'1½"	23'9"	24,900
1965	26'7"	25'11"	24'1½"	23'9"	24,700
1967	26'7"	25'11"	24'1½"	23'9"	24,700
1968	26'7"	25'11"	24'1½"	23'9"	24,700
1969	26'7"	25'11"	24'1½"	23'9"	24,700
1970	26'11½"	26'4"	25'4"	24'2"	25,600
1971	26'11½"	26'4"	25'4"	24'2"	25,600
1973	26'11½"	26'4"	25'4"	25'2½"	25,600
1975	27'9"	27'1"	27'1"	26'9½"	26,400

TABLE 16 CLASS 7 LOAD LINES FOR 1970 AND 1975

Year	Draft in feet: MidSummer	Sum	Int	Win	MS Cap
US 1975 avr.	28.41'	27.71'	27.42'	27.23'	26504tons
US 1970 avr.	27.63	26.84'	25.83	24.62	25098
Difference	+ .78	+ .87	+1.59	+1.61	+1406
Can 1975 avr.	27.83	27.37	26.43	26.24	27995
Can 1970 avr.	27.79	27.12	25.89	24.91	27572
Difference	+ .04	+ .25	+ .54	+1.33	+ 423
Tot 1975 avr.	27.94	27.44	26.63	26.44	27702
Tot 1970 avr.	27.75	27.06	25.87	24.85	27032
Difference	+ .19	+ .38	+ .76	+1.59	+ 670

Source: Greenwood 1970, 1975.

TABLE 17 COMPARISON OF IGLLB DATA CLASS 7 MIDSUMMER DRAFT IN 1970 WITH GREENWOOD DERIVED INFORMATION

	Drafts in Feet	
	IGLLB 1970	Greenwood 1970
U.S. Class 7	27.5	27.63
Canadian Class 7	27.7	27.79

Source: Greenwood 1970; IGLLB 1973, Appendix E, pp. 77, 80.

TABLE 18 GREAT LAKES VESSELS ON ORDER

Vessel or Hull #	Ready	O.A. Length	Depth	Draft: MS S I W
R. Blough	1972	858'	41'6"	27'10" ⟶
S. Cort	1972	1000	49	27'10" ⟶
#905	1976	1000	50	? ⟶
#906	1977	1000	50	? ⟶
#907	1978	1000	50	? ⟶
#714	1976	770	52	30' ⟶
#716	1977	1000	56	? ⟶
#717	1978	1000	56	? ⟶

Source: Greenwood 1975.
Note: MS—Midsummer; S—Summer; I—Intermediate; W—Winter.

The depth dimensions from Table 18 must then be compared with information from U.S. Coast Guard (1971) regulations on minimum allowable freeboards (Table 45.15-100(a)-"Reduced Basic Minimum Summer Freeboards for Steamers on Great Lakes Voyages"). Taking hull #716 with depth 56' for example: the minimum freeboard from Coast Guard regulations is 184'4" (U.S. Coast Guard 1971). The potential summer draft equals the depth minus minimum freeboard or 40.6 feet.

It is not plausible that shipowners would be letting contracts for vessels which would have unusable draft potential. A significant effort probably is underway by the industry to achieve at least a 32 foot (and possibly deeper) controlling depth. The hydrologic, environmental, and economic consequences of such a proposal would conceivably be much more severe than the regulatory plans now being considered. The Great Lakes Basin Commission (1975) estimated that 2.138 billion dollars would be required to dredge the entire Great Lakes system to 32'. The estimated cost to the State of Wisconsin for increasing the control depth to 31' for the Port of Milwaukee alone would be $54.1 million.

Length of the Great Lakes Shipping Season

An inexplicable inconsistency regarding the lengths of the various shipping seasons deserves mention. Since there are significant allowable draft differences between seasonal load lines, considerable economic benefits depend on the number of days that the Great Lakes fleet can load to maximum allowable seasonal draft. Table 19 compares the lengths of the various seasons as reported by the IGLLB, Greenwood (1970 and 1975), and official Coast Guard regulations. The official ruling on seasonal load limits is found in the Coast Guard regulations manual, Load Line Regulations:

> 45.01-75 Seasonal Load lines.
>
> 45.01-75(a) For load line purposes there is hereby established for the Great Lakes a winter, intermediate, summer, and for tankers and cargo vessels (see Sections 45.01-15 and 45.01-17) a midsummer season, and load lines applicable to each season are established by the regulations in this part. The winter season shall be that period from November 1 through April 15 of the next year, the intermediate seasons from October 1 through October 31, and the summer season from May 1 through September 30. The midsummer season shall be the portion of the summer season from May 1 through September 15 which shall be applicable only in those cases where midsummer season load lines are permitted.

Apparently the IGLLB based their shipping season length estimates on the ocean shipping season formula of 1970 which does call for a midsummer season of 123 days, summer - 30 days, intermediate - 46 days, and winter - 166 days. It is difficult to understand why the IGLLB found it necessary to employ season lengths significantly different from those imposed by regulatory agencies, especially when the enforced midsummer high use season is 15 days longer than what the report chose to use.

TABLE 19 SEASON LENGTH COMPARISON USING VARIOUS SOURCES

Source	Midsummer: Dates in Force	Midsummer: # Days	Summer	Intermediate	Winter
IGLLB for US & Canadian Fleet	May 16 - September 15	123	May 1-15 September 16-30	April 16-30 October 1-31	November 1 - April 15
Greenwood 1970 Actual Great Lakes Season	May 1 - September 15	138	September 16-30	April 16-30 October 1-31	November 1-30
Greenwood 1975 Actual Great Lakes Season	May 1 - September 15	138	April 16-30 September 16-30	April 1-15 October 1-31	November 1 - December 31
Official Coast Guard Regulations	May 1 - September 15	138	September 16-30	April 16-30 October 1-31	November 1 - April 15

Source: IGLLB 1973, Appendix E; Greenwood 1970 and 1975; U.S. Coast Guard 1971.

SHIP NEEDS PROJECTIONS

The IGLLB report carefully projected the number of ships needed for 1970, 1995, and 2020 by class and registry. Information from Greenwood (1970 and 1975) indicates that the IGLLB overestimated the number of ships in use for 1970 (Table 20).

TABLE 20 PROJECTIONS OF THE NUMBER OF GREAT LAKES SHIPS IN SERVICE -- 1970, 1975

Class	Reg.	IGLLB Projection for 1970	1970 Actual	1975 Actual
1	US	0	0	12
	Can	9.7	26	22
2	US	6.5	3	4
	Can	6.2	3	4
3 & 4	US	40.7	21	24
	Can	9.6	17	17
5	US	101.5	92	95
	Can	14.8	14	16
6	US	13.4	8	14
	Can	10.9	8	11
7	US	8.8	12	11
	Can	53.6	36	45
8	US	0	0	7
	Can	0	0	1
9	US	0	0	1
	Can	0	0	0
10	US	0	0	2
	Can	0	0	0
	Total US	170.9	136	170
	Total Can	104.8	104	116
	Grand Total	275.7	240	286

Source: Greenwood 1970 and 1975.

EFFECT OF EN ROUTE FUEL CONSUMPTION ON SHIP DRAFTS

Ships might overload in the Great Lakes region relative to channel and lock controlling depths at Sault Ste. Marie and then rely on draft reduction from fuel consumption enroute to sail through the Soo locks with minimum possible clearance and maximum cargo. This is probably not a viable practice due to the relatively small amount of fuel consumed. Using a class 7 carrier as an example fuel consumption from Duluth to Sault Ste. Marie would be 58 tons which is less than one-half inch of draft.*

*Fuel Consumption - 300 Bbls/day X 55 gal/Bbl = 16,500 gal/day
Duluth to Soo distance = 400 mi/17 mph speed - 23.5 hr trip
Trip time rounded to full 24 hour day.
16,500 gal/trip X approx. 7 lb/gal = 115,500 lbs/trip
115,500 lbs = 58 tons

The approximate capacity per inch of draft for a class 7 vessel is 110-130 gross tons. Therefore, fuel consumption en route to the Soo would only be on the order of 1/2 inch of draft.

ATTACHMENT B

Critical Water Levels

Mike Spranger and Charles Falkner

A critical water level is defined as that lake level below which a ship with a given draft in a channel or harbor of specified controlled depth cannot load to capacity. These critical water levels can be calculated directly for each lake based on the Low Water Datum and the estimated safety factor of 1.5 feet. If this critical water level is below the absolute minimum water level from regulation plans BOC and SO-901, then there is no possibility of a benefit to navigation.

In this attachment tables of critical water levels are given by vessel class for 1970 based on IGLLB data (IGLLB 1973, Appendix E, p. E-77) and the following lake level data:

	LWD (ft)	Absolute Minimum (ft)
Superior	600.0	598.36
Michigan-Huron	576.8	575.15
Erie	568.6	567.95
Ontario	242.8	241.29

For each vessel class there are four periods corresponding to the load line limitations: 1) April and October; 2) May and September; 3) June, July, and August; and 4) November and December. Tables 21-24 show critical water levels on each lake for each commodity based on the 27-foot navigation channel control depth.

Tables 25-27 provide the same information for a selected commodity at three different major ports and contrast the critical water level at harbor control depth with that in the navigation channels. An analysis of these tables indicate that there are potential benefits only for vessel classes 6 and above due to the constraint of navigation channel depth.

TABLE 21 CRITICAL WATER LEVELS FOR IRON ORE SHIPMENTS ON THE GREAT LAKES

Vessel Class	Period	Load Limit	CRITICAL WATER LEVEL (27') S	M-H	Erie	O
IV	(1)	20.3	594.8*	571.6*	563.4*	237.6*
	(2)	21.1	595.6*	572.4*	564.2*	238.4*
	(3)	21.5	596.0*	572.8*	564.0*	238.8*
	(4)	19.4	593.9*	570.7*	562.5*	236.7*
V	(1)	21.9	596.4*	573.2*	565.0*	239.2*
	(2)	22.7	597.2*	574.0*	565.8*	240.0*
	(3)	23.2	597.7*	574.5*	566.3*	240.5*
	(4)	21.1	596.6*	573.4*	565.2*	239.4*
VI	(1)	24.0	598.5	575.3	567.1*	241.3
	(2)	24.9	599.4	576.2	568.0	242.2
	(3)	25.5	600.0	576.8	568.6	242.8
	(4)	23.6	598.1*	574.9*	566.7*	240.9*
VII	(1)	25.8	600.3	577.1	568.9	243.1
	(2)	26.8	601.3	578.1	569.9	244.1
	(3)	27.5	602.0	578.8	570.6	244.0
	(4)	25.7	600.2	577.0	568.8	243.0

Source: IGLLB 1973, Appendix E, p. 3-77.
*Below absolute minimum

TABLE 22 CRITICAL WATER LEVELS FOR COAL SHIPMENTS ON THE GREAT LAKES

Vessel Class	Period	Load Limit	CRITICAL WATER LEVEL (27') S	M-H	Erie	O
II	(1)	19.4	593.9*	570.5*	562.5*	236.7*
	(2)	19.8	594.3*	571.9*	562.9*	237.1*
	(3)	20.0	594.5*	571.1*	563.1*	237.3*
	(4)	18.9	593.4*	570.0*	562.0*	236.2*
III	(1)	20.0	594.5*	571.3*	563.1*	237.3*
	(2)	20.7	595.2*	572.0*	563.8*	238.0*
	(3)	21.1	595.6*	572.4*	564.2*	238.4*
	(4)	19.2	593.7*	570.5*	562.3*	236.5*
IV	(1)	20.6	593.1*	571.9*	563.7*	237.9*
	(2)	21.4	593.9*	572.7*	564.5*	238.7*
	(3)	21.7	596.2*	573.0*	564.8*	239.0*
	(4)	19.6	594.1*	570.9*	562.7*	236.9*
V	(1)	22.2	596.7*	573.5*	565.3*	239.5*
	(2)	23.0	597.5*	574.3*	566.1*	240.3*
	(3)	23.5	598.0*	574.8*	566.6*	240.8*
	(4)	21.1	595.6*	572.4*	564.2*	238.4*
VI	(1)	25.3	599.8	576.6	568.4	242.6
	(2)	26.3	600.8	577.6	569.4	243.6
	(3)	26.9	601.4	578.2	570.0	244.2
	(4)	24.1	598.6	575.4	567.2*	241.4

Source: IGLLB 1973, Appendix E, p. 3-77.
*Below absolute minimum

Table 23 Critical Water Levels for Grain Shipments on the Great Lakes

Vessel Class	Period	Load Limit	CRITICAL WATER LEVEL (27') S	M-H	Erie	O
II	(1)	20.1	594.6*	571.4*	563.2*	237.4*
	(2)	20.6	595.1*	571.9*	563.7*	237.9*
	(3)	20.9	595.4*	572.2*	564.0*	238.2*
	(4)	19.5	594.0*	570.8*	562.6*	236.8*
III	(1)	20.6	595.1*	571.9*	563.7*	237.9*
	(2)	21.3	595.8*	572.6*	564.4*	238.6*
	(3)	21.7	596.2*	573.0*	564.8*	239.0*
	(4)	19.7	594.2*	571.0*	563.8*	237.0*
IV	(1)	20.3	594.8*	571.6*	563.4*	237.6*
	(2)	21.0	595.5*	572.3*	564.1*	238.3*
	(3)	21.4	595.9*	572.7*	564.5*	238.7*
	(4)	19.3	593.8*	570.6*	562.4*	236.6*
V	(1)	21.6	596.1*	572.9*	564.7*	238.9*
	(2)	22.4	596.9*	573.7*	565.5*	239.7*
	(3)	22.9	597.4*	574.2*	566.0*	240.2*
	(4)	20.5	595.0*	571.8*	563.0*	237.8*

Source: IGLLB, 1973, Appendix E, p. E-77.
*Below absolute minimum

Table 24 Critical Water Levels for Limestone Shipments on the Great Lakes

Vessel Class	Period	Load Limit	CRITICAL WATER LEVEL (27') S	M-H	Erie	O
II	(1)	19.4	593.9*	570.7*	562.5*	236.7*
	(2)	19.8	594.3*	571.1*	562.9*	237.1*
	(3)	20.0	594.5*	571.3*	563.1*	237.3*
	(4)	18.9	593.4*	570.2*	562.0*	236.2*
III	(1)	20.0	594.5*	571.3*	563.1*	237.3*
	(2)	20.7	595.2*	572.0*	563.8*	238.0*
	(3)	21.1	595.6*	572.4*	564.2*	238.4*
	(4)	19.2	593.7*	570.5*	562.3*	236.5*
IV	(1)	20.6	595.1*	571.9*	563.7*	237.9*
	(2)	21.4	595.9*	572.7*	564.5*	238.7*
	(3)	21.7	596.2*	573.0*	564.8*	239.0*
	(4)	19.6	594.1*	570.9*	562.7*	236.9*
V	(1)	22.2	596.7*	573.5*	565.3*	239.5*
	(2)	23.0	597.5*	574.3*	566.1*	240.3*
	(3)	23.5	598.0*	574.8*	566.0*	240.8*
	(4)	21.1	595.6*	572.4*	564.2*	238.4*
VI	(1)	25.3	599.8	576.6	568.4	242.6
	(2)	26.3	600.8	577.6	569.4	243.6
	(3)	26.9	601.4	578.2	570.0	244.2
	(4)	24.1	598.6	575.4	567.2*	241.4

Source: IGLLB, 1973, Appendix E, p. E-77.
*Below absolute minimum

TABLE 25 CLEVELAND — IRON ORE

Controlling depth of 23' for unloading port; all loading ports of iron ore have harbors of at least 27' depth.

Class	Period	Depth (27')	Critical Water Level (27')	Critical Water Level (23')
IV	(1)	20.3	563.4*	566.4*
	(2)	21.1	564.2*	568.2
	(3)	21.5	564.0*	568.6
	(4)	19.4	562.5*	566.5*
V	(1)	21.9	565.0*	569.0
	(2)	22.7	565.8*	569.8
	(3)	23.2	566.3*	570.3
	(4)	21.1	564.2*	568.2
VI	(1)	24.0	567.1*	571.1
	(2)	24.9	568.0	571.5
	(3)	25.5	568.6	572.6
	(4)	23.6	566.7*	570.1
VII	(1)	25.8	568.9	572.9
	(2)	26.8	569.9	573.9
	(3)	27.5	570.6	574.0
	(4)	25.7	568.8	572.8

Source: IGLLB 1973, Appendix E, p. E-77.

*Below absolute minimum

TABLE 26 BUFFALO — GRAIN

Controlling Depth 21' — 23'

Class	Period	Load Limits	Critical Water Level (27')	Critical Water Level (21')
II	(1)	20.1	563.2*	569.2
	(2)	20.6	563.7*	569.7
	(3)	20.9	564.0*	570.0
	(4)	19.5	562.6*	568.6
III	(1)	20.6	563.7*	569.7
	(2)	21.3	564.4*	570.4
	(3)	21.7	564.8*	570.8
	(4)	19.7	562.8*	568.8
IV	(1)	20.3	563.4*	569.4
	(2)	21.0	564.1*	570.1
	(3)	21.4	564.5*	570.5
	(4)	19.3	562.4*	568.4
V	(1)	21.6	564.7*	570.7
	(2)	22.4	565.5*	571.5
	(3)	22.9	566.0*	572.0
	(4)	20.5	563.0*	570.0

Source: IGLLB 1973, Appendix E, p. E-77.

*Below absolute minimum

TABLE 27 MILWAUKEE — COAL
Controlling Depth 21'

Class	Period	Load Limits	Critical Water Level 27'	Critical Water Level 21'
II	(1)	19.4	570.7*	576.7*
	(2)	19.8	571.1*	577.1
	(3)	20.0	571.3*	577.3
	(4)	18.9	570.2*	575.2*
III	(1)	20.0	571.3*	577.3
	(2)	20.7	572.0*	577.0
	(3)	21.1	572.4*	578.4
	(4)	19.2	570.5*	576.5*
IV	(1)	20.6	571.9*	577.9
	(2)	21.4	572.7*	578.7
	(3)	21.7	573.0*	579.0
	(4)	19.6	570.9*	576.9
V	(1)	22.2	573.5*	579.5
	(2)	23.0	574.3*	580.3
	(3)	23.5	574.8*	580.8
	(4)	21.1	572.4*	578.4
VI	(1)	25.3	576.6	582.6
	(2)	26.3	577.6	583.6
	(3)	26.9	578.2	584.2
	(4)	24.1	575.4	581.4

Source: IGLLB 1973, Appendix E, p. E-77.

* Below absolute minimum.

ATTACHMENT C

BRIEF SYNOPSIS OF THE GREAT LAKES BASIN NAVIGATION SYSTEM

Mike Spranger

ST. MARYS RIVER SYSTEM

The St. Marys River, which forms the only outlet from Lake Superior, falls approximately 22 feet from Lake Superior to Lakes Michigan-Huron. At Sault Ste. Marie, the river is divided into an upstream and downstream reach by existing regulatory facilities. Over the past 118 years, man-made alterations have been made intermittently to the various channels of the St. Marys River for navigation purposes. At present, in the Upper St. Marys River a navigation channel, having a minimum depth of 28 feet below LWD (Low Water Datum) and a minimum width of 1,200 feet is maintained. In the lower St. Marys River a navigation channel, with a minimum depth of 27 feet below LWD and minimum widths of 399 feet and 600 feet for one-way and two-way traffic respectfully is maintained.

Historical changes in the navigation facilities are presented below:

1798 First lock at Sault Ste. Marie, built by the North West Company on the Canadian side of the river. The lock was 38 feet long, 9 feet wide, and had a lift of 9 feet. Lock did not completely circumvent the rapids, thus a tow path was made along the shore for beasts of burden to pull vessels through the remainder of the rapids. The lock was used until 1814, when it was destroyed by United States troops in the war of that era.

1855 First ship canal at Sault Ste. Marie was completed and opened, known as the New State Canal. The canal was 5,700 feet long, 64 feet wide at the bottom and 100 feet at the surface and 13 feet deep. The two locks in the canal were each 350 feet long, 70 feet wide, and 11½ feet in depth over the sills, and had a lift of 9 feet.

1881 Weitzel Lock built at Sault Ste. Marie under the direction of General Orlando M. Poe. The lock was 515 feet long, 80 feet wide, and had a lift of 18 feet.

1895* First large lock on the Canadian side of the rapids at Sault Ste. Marie built. The lock is 900 feet long, 60 feet wide, and 22 feet deep.

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* Presently in operation.

1914* Davis Lock built at Sault Ste. Marie. The lock is 1,350 feet long, 80 feet wide, and 23 feet in depth over the sills.

1919* Sabin Lock built at Sault Ste. Marie. The lock is 1,350 feet long, 80 feet wide, and 23 feet in depth over the sills.

1943* MacArthur Lock built at Sault Ste. Marie on the site of the old Weitzel Lock. The lock is 800 feet long, 80 feet wide, and has a depth of 31 feet.

1968* Poe Lock built at Sault Ste. Marie. The lock is 1,200 feet long, 110 feet wide, and 32 feet in depth over the sills. It is capable of handling lake vessels, 1,000 feet long and 105 feet wide.

ST. CLAIR—DETROIT RIVER SYSTEM

The St. Clair-Detroit River system is divided into three distinct parts: The St. Clair River, which has a length of about 38 miles; Lake St. Clair, extending between the mouth of the St. Clair River and the head of the Detroit River, a distance of about 16 miles, and the Detroit River which extends about 32 miles to Lake Erie. The fall in the water level from Lakes Michigan-Huron to Lake St. Clair is about 5 feet and from Lake St. Clair to Lake Erie it is about 3 feet.

ST. CLAIR RIVER

The St. Clair River can be separated into three reaches. The upper contracted reach, extending downstream from Lake Huron for about 4 miles, is about 800 feet wide at the narrowest point and has mid-channel depths varying from about 30 to 70 feet. The middle reach extends downstream over the next 23 miles, is about ½ mile wide, and has channel depths varying from about 27 to 50 feet. The lower reach extends about 11 miles to Lake St. Clair and it is in this reach that the river begins to divide into a number of channels which flow across the delta shaped area called the St. Clair Flats. It is in this latter area where major changes in the channels have taken place through private, Canadian, and U.S. Government dredging operations.

LAKE ST. CLAIR

Lake St. Clair, a shallow embayment in the St. Clair Detroit River system, occupies a wide expansive, relatively shallow basin having an average depth of about 10 feet with low, marshy shores. The shallow depth requires dredged commercial navigation channel throughout its length. Improvements for navigation have provided a navigation channel 27.5 feet deep and 800 feet wide.

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* Presently in operation.

DETROIT RIVER

The Detroit River is characterized by relatively uniform cross sections, having a width of about ½ mile and channel depths varying from 27 to 50 feet.

Historical changes in the St. Clair and Detroit River navigation channels are as follows:

1936 A minimum 25-foot navigation channel was constructed throughout the St. Clair-Detroit River system in 1932-1936.

1962 A minimum 27-foot deep-draft channel currently exists throughout the entire length of the system as the result of a deepening program initiated in 1957 and completed in 1962.

Other unmaintained navigational channels exist throughout the St. Clair-Detroit system, ranging in depths from 21 feet to 25 feet. Except for the work of man, the natural channels in the St. Clair and Detroit Rivers have remained virtually unchanged due to the stability of the heavy blue clay which constitutes their bed.

NIAGARA RIVER SYSTEM

The Niagara River, about 36 miles in length, links Lake Erie with Lake Ontario. The average fall over its course is 326 feet about half of which is concentrated at Niagara Falls, located approximately 22 miles below the head of the river. The Niagara River consists of three major reaches: The Upper Niagara River; the Niagara Cascades and Falls, and the Lower Niagara River extending from the foot of the falls to Lake Ontario. In order to traverse this natural barrier to commercial navigation, two artificial channels, the Welland and Black Rock Canals, have been built.

1932 The Welland Canal

The Welland Canal, with a minimum depth of 27 feet, connects Lake Erie at Port Colborne, Ontario, approximately 18 miles west of the head of the Niagara River, with Lake Ontario at Port Weller, Ontario, 9 miles west of the mouth of the river. The canal is approximately 27 miles long and overcomes a difference in elevation of about 326 feet by a series of 7 lift locks and 1 guard lock. Ships 730 feet or less in overall length and 80 feet or less in width may transit the canal.

The Black Rock Canal

The Black Rock Canal has a depth of about 21 feet. It provides an alternate route around the constricted and shallow reach at the head of the Niagara River. Extending from Buffalo Harbor to the river above Strawberry Island, the canal is separated from the river by a series of stone and concrete walls and by Squaw Island. The Black Rock Lock, which has a lift of about 5 feet, is located near the lower end of the canal. Niagara Falls prevents ships from using this canal for commercial purposes.

ST. LAWRENCE RIVER SYSTEM

The St. Lawrence River forms the natural outlet of the Great Lakes Drainage basin. From its headwaters on Lake Ontario at Kingston, Ontario, the river flows generally in a northeasterly direction to its outlet on the Gulf of St Lawrence, at Father Point, Quebec, a distance of some 530 miles. The river falls approximately 245 feet in this distance. To enable overseas commercial shipping to enter the Great Lakes, the St. Lawrence Seaway and the St. Lawrence Ship Channel were opened in 1959.

From Montreal to Lake Ontario, a vessel travels 182 miles and rises over 225 feet in the St. Lawrence Seaway. In the course of this distance, seven locks have been constructed; five are operated by the St. Lawrence Seaway Authority of Canada and two are operated by the U.S. St. Lawrence Seaway Development Corporation. Works of the Federal Seaway agencies of Canada and the U.S. provide a 27-foot navigation channel along this route.

The St. Lawrence Ship Canal, some 200 miles in length, refers to the main sailing course of the St. Lawrence River between the Port of Montreal and 40 miles downstream of Quebec City at which point the river is naturally deep. The main navigation channel has a maintained depth of 35 feet below LWD and a minimum width of 800 feet. The normal fall in water surface elevation between Montreal and Quebec City is about 25 feet.

ATTACHMENT D

Incidence and Influence of Shallow Draft Harbors Within the Great Lakes Navigation System

Mike Spranger

In commercial navigation on the Great Lakes, depths are the major constraints to navigation. With few exceptions, the Lakes proper have ample depth for navigation. It is the connecting waters and harbors where depths are a problem. Throughout the entire Great Lakes and St. Lawrence Seaway system, an authorized navigable channel is maintained that is kept at a minimum depth of 27 feet below water datum (LWD). All depths in the Great Lakes navigation system are given in feet below LWD. LWD represents the average low levels of the Great Lakes, compiled from a consideration of the recorded levels since the turn of the century. The present low water datum planes for each of the lakes were established in 1933. A safety load line limit is required on vessels transporting cargo on the lakes. This limit is approximately 1.25 feet above the maximum draft to which a vessel may load. Thus, for a 27-foot channel depth, the load line limit for loaded vessels would be 25 feet, nine inches. Noting that the navigation channel is minimally set at 27 feet, this means that a vessel can only load to a maximum draft of 25 feet, 9 inches when travelling through the channels, if at LWD.

There are further restrictions placed on vessels travelling within the lakes. The various locks place a length and beam limit on vessels. The maximum size vessel going through the Sault Ste. Marie Locks (connecting Lake Superior with Lakes Michigan-Huron) is one with a length of 1,000 feet and a beam of 105 feet. Vessels that travel through the Sault Ste. Marie Locks (connecting Lake Erie with Lake Ontario and the St. Lawrence Seaway) are limited to a maximum length of 730 feet and a beam of not more than 75.5 feet. In addition, various characteristics of the lake harbors further limit vessel size. There are many harbors that have shallow draft (less than 27 foot minimum draft). Also the docking facilities of various harbors place over-all length limitations on ships using its facilities.

Depths available during the navigation season are generally equal to or greater than the project depths, except during extreme low water years, such as those occurring during the mid-1920s, mid-1930s, and early 1960s. Because an inch of draft represents up to 110 tons of cargo on the freighters now in use, and 200-plus tons per inch on the new 800 to 1,000 foot ships, any lowering of the water level can cause severe losses in the quantity of cargo moved and in the unit cost of cargo movements. From a navigational standpoint, then, it is desirable that water levels be as high as possible and at least as high as LWD. Thus, navigation interests would favor a regulation plan that would accomplish this purpose.

As previously noted, there are a number of shallow water harbors in the Great Lakes (Table 28). This is a major deterrent to the shipping interests since they would like to see their ships loaded to maximum capacity. With the assumed trend toward larger ships (Table 29), it is apparent that these shallow water harbors will impose vessel size constraints. It is evident that the larger the ship size, the greater the constraint will be placed on it. A major benefit to the navigation interests will result if lake level regulations ensure high lake levels (27 foot channels and greater). In the study the Levels Board assumes that all harbors will be dredged to 27-foot depths below LWD by 1995. For the 1970 calculations, the IGLLB used a weighted average of all the harbors thereby hiding within this weighted average the load line limits imposed by the shallow draft harbors. The following report critically examines these assumptions. The four major commodities transported on the lakes will be examined—their loading/unloading ports will be analyzed as to their physical characteristics that may limit vessel class in fully utilizing the port. The various ports of Wisconsin will also be examined, with respect to harbor depths.

Iron Ore

More iron ore is handled at lake ports than any other commodity. Most iron ore shipments originate from the shores of Lake Superior in the states of Minnesota, Wisconsin, and Michigan. The mines of the Mesabi Range provide most of this ore. In 1973 Duluth-Superior, the twin ports that function as the primary outlet for the Mesabi Range, handled 29.8 million tons of iron ore. The majority of the iron ore originating in the Lake Superior region passes down through Lake Huron and the St. Clair River to steel production plants on Lake Erie. Most of the remainder is transported down to steel furnaces at the south end of Lake Michigan.

Looking at the harbor and docking facilities of the seven major loading ports in the United States for iron ore, all of them have at least one facility that can accommodate a 27-foot draft. In the case of the major unloading ports, 10 of 13 (77%) have at least one facility of 27-foot draft. Thus, only Ashtabula, Cleveland, and Huron, all cities in Ohio, are shallow draft harbors with respect to the shipment of iron ore.

If we assume that the lake level is at LWD and that the ships are loaded to their maximum capacity (allowing for the 1.25 foot safety factor), it is evident that even these facilities will limit the full utilization of the Great Lakes fleet. In the case of the loading ports, only vessels up to class size 6 (4 ports) and class size 7 (3 ports) could be loaded to maximum capacity.

In the case of the unloading ports, only two ports could accommodate fully loaded class 7 vessels, with eight ports only accommodating fully loaded vessels of class 6 or less. Of the three shallow draft unloading ports, Cleveland would only be able to accommodate vessels up to class 5, while the other two shallow draft harbors would only be able to accommodate fully loaded vessels up to class 4.

TABLE 28 NUMBER OF DEEP/SHALLOW DRAFT HARBORS AND DOCKING FACILITIES WITHIN THE GREAT LAKES

Commodity		Lake	Harbors		Dock Facilities	
			Deep Draft	Shallow Draft	Deep Draft	Shallow Draft
Iron Ore	loading ports	Superior	6	0	11	1
		Michigan-Huron	1	0	1	0
	unloading ports	Erie	5	3	7	10
		Michigan-Huron	5	0	8	4
Coal	loading ports	Superior	1	0	1	0
		Erie	2	3	8	4
		Michigan-Huron	1	0	1	0
	unloading ports	Superior	2	7	2	9
		Michigan-Huron	2	32	2	53
		Erie	0	4	0	5
Limestone	loading ports	Michigan-Huron	2	3	2	6
		Erie	0	2	0	2
	unloading ports	Michigan-Huron	3	5	4	27
		Erie	3	1	7	23
Grain*	loading ports	Superior	2	0	11	4
		Michigan-Huron	1	3	5	7
		Erie	1	4	3	11
		Ontario	0	1	0	1

Source: Greenwood 1970-1975.

* In case of grain, most ports load and unload various types of grain.

TABLE 29 COMMERCIAL NAVIGATION VESSEL DRAFTS AT MAXIMUM CAPACITY

Class No.	Commodity*	United States 1970	United States 1995	United States 2020	Canada 1970	Canada 1995	Canada 2020
1.	I				15.1		
	C				15.1	23.5	
	L					23.5	
	G				15.1		
2.	I				19.6		
	C	18.0			19.6	21.1	
	L	20.0			19.6	21.1	
	G	21.0			19.6		
3.	I						
	C	20.8					
	L	21.1					
	G	21.7					
4.	I	21.5			22.3		
	C	21.5	21.5		22.3	23.8	
	L	21.7	22.5		22.3	23.8	
	G	21.4			22.3	23.8	
5.	I	23.2	25.6		24.7	24.6	
	C	21.9	21.6		24.7	24.6	
	L	23.5	25.6		24.7	24.6	
	G	22.9	25.6		24.7	22.9	
6.	I	25.5	26.3	26.3	26.0	26.4	
	C	25.2	22.6	22.6	26.0	26.4	
	L	26.9	26.3	26.3	26.0	26.4	
	G		26.3	26.3	26.0	24.0	
7.	I	27.5	27.2	27.2	27.7	27.2	27.2
	C		22.2	22.2	27.7	27.2	27.2
	L		27.2	27.2	27.7	27.2	27.2
	G		27.2	27.2	27.7	27.2	27.2
8.	I		29.5	29.5			
	C			25.3			
	L		29.5	29.5			
	G			29.5			
9.	I		31.0	31.0			
	C			26.6			
	L		31.0	31.0			
	G			31.0			
10.	I		32.0	32.0		32.0	32.0
	C			27.3			27.3
	L			32.0			32.0
	G			32.0		32.0	32.0

Source: IGLLB, 1973, Appendix E, pp. E-77-82.
*I - Iron, C - Coal, L - Limestone, G - Grain.

Note: Class Numbers (1) $<$ 400 feet, (2) 400-499 feet, (3) 500-549 feet, etc.

The IGLLB assumed that all iron ore will be transported in vessels of class 6 or greater by 1995 and that 86% of the iron ore will be transported in vessels of class 8 or greater by 2020 (IGLLB 1973, Appendix E, p. E-47). It is evident that if these assumptions are to come about, massive dredging operations of the main navigation channel (now at 27 feet) and the loading/unloading harbors will have to be made in the near future, along with extensive renovation of the docking facilities of the unloading ports. If these operations are not made, then it appears that the super-ships now under construction will be under-utilized in the future.

COAL

Coal traffic is concentrated on Lake Erie, with Huron, Michigan, and Ontario having lesser roles. Toledo is the most important loading port, shipping 14.5 million tons in 1973. Destinations for coal are generally areas where electric utilities and the iron and steel industry are preponderant. Due to the effect of environmental controls on the use of high sulphur coal, there is some evidence to suggest a change in the coal traffic. The Port of Superior is presently building a $30 million coal handling facility for the shipment of low-sulphur Rocky Mountain coal. The present estimates available suggest that Superior may ship as much as 30 million tons annually in the future.

Looking at the present coal loading ports, only four of the seven (57%) have harbor and docking facilities of 27-foot depths. The three shallow draft loading harbors are Ashtabula, Ohio; Lorain, Ohio, and Sandusky, Ohio.

In the case of the unloading ports, only three of the 47 unloading ports (6.4%) have harbor and dock facilities of 27-foot depths. Thus the majority of coal unloading ports are shallow draft harbors. Due to the physical characteristics of coal, vessel classes up to and including class 8 can be loaded to their maximum capacity and still utilize the 27-foot channel depths, but because most unloading ports are shallow draft harbors, this fact is not very relevant. In addition to the draft limitations of these harbors, many of the docking facilities are antiquated and impose an over-all length limitation on vessels utilizing the facilities.

If we assume that the lake level is at LWD and that the ships are loaded to their maximum capacity, taking into account the draft and over-all length limitations, it is apparent that ship size is severely limited in these unloading ports. Only one port could accommodate fully loaded vessels up to class size 10, two ports could accommodate vessels up to class 8, nine could accommodate vessels up to class 7, four ports could accommodate vessels up to class 5, seven ports could accommodate vessels up to class 3, seventeen ports could accommodate vessels up to class 2, and seven ports could accommodate fully loaded vessels below the class 2 designation.

The IGLLB assumed that by 1995, 50% of coal shipments will be transported by vessels of class 6 and 7, and that by 2020 100% of the coal shipments will be transported by vessels in the classes 6—10 (IGLLB 1973, Appendix E, p. E-47). Since 35 of the 47 unloading ports (74%) can only presently accommodate vessels of class 5 or less, it is apparent that massive dredging of the harbors and renovation of the docking facilities will have to take place if these assumptions are to come about.

LIMESTONE

Almost all of the limestone traffic is shipped by lakes. The major loading ports for limestone are Calcite, Stoneport, and Port Inland, Michigan; and Port Dolomite, Michigan for dolomite. Most of the traffic is unloaded near steel mills at Detroit, Gary, Chicago, and Cleveland. Limestone is a low-value commodity, with an inability to support much transportation cost. Fortunately, limestone is not only produced at lakeside, it is also generally consumed at lakeside, which minimizes the cost of getting it to or from the lake vessels. These two factors have resulted in the development of a sophisticated triangular movement of coal and limestone, designed to provide for a viable, low-cost tranpsortation system. Coal moves via self-unloaders out of the Lake Erie ports or Chicago destined for lakeside cities on Lake Michigan or Huron. Once the coal is unloaded, the self-unloaders move in ballast to a port where they load limestone and then sail to its port of destination. Because this enables the vessel to sail with as high a load factor as possible, it reduces the overall transportation cost. Thus, a complementary relationship exists between the transportation of coal and limestone in the Great Lakes.

Looking at the major limestone loading ports, only two of the seven loading ports (39%) have harbor and docking facilities of 27-foot depths. In the case of the major unloading ports, six of the twelve ports (50%) have harbor facilities of 27-foot depths.

Again, assuming that the lake level is at LWD and that the ships are loaded to their maximum capacity, it is apparent that vessel size will be limited. In the case of the loading ports, only one port would be able to accommodate a fully loaded vessel of class 7, one port would be able to accommodate a vessel of class 6, three ports could accommodate vessels up to class 4, and two ports could accommodate vessels up to class 2 or less. Thus, eleven of the twelve (92%) unloading ports can only accommodate fully loaded vessels of class 5 or less.

The IGLLB assumed that by 1995 60% of the limestone will be transported in vessels of class 6 or better; and that by 2020 virtually all of the limestone will be transported in vessels of size 6 or larger, with 88% transported in vessels of class 8 or larger (IGLLB 1973, Appendix E, p. E-47). Again, as in the case of coal, it appears that massive dredging and renovation of the port facilities would have to be undertaken in the near future, in order to make these future projections valid.

Grain

Second only to the Canadian port of Thunder Bay, the twin port of Duluth-Superior is the largest grain loading port on the Great Lakes. In the case of wheat, 41.8 million tons were shipped from the ports of Duluth-Superior to various United States ports in 1973. The majority of the American domestic wheat is unloaded at Buffalo with its large milling complex, although smaller quantities do go to Cleveland, Chicago, and Oswego, New York. Such grains as oats, barley, corn, and rye also follow the same type of pattern as wheat, with the majority going to Buffalo, although there are large amounts that go to Milwaukee and Chicago where it is used in the production of malt.

Of the major grain ports, only four of the twelve ports (25%) have harbor and docking facilities with depths of 27 feet. In fact the major unloading port of Buffalo has a draft limitation of about 23 feet at LWD. As in previous cases, these grain ports are antiquated and impose an overall length limitation on vessels entering its harbors, which further constrain the size of ship that can utilize its facilities. Taking this into consideration, only one port can accommodate a fully loaded vessel of class 6 or less, four ports can accommodate vessels of class 5 or less, two ports can accommodate vessels of class 3 or less, and three ports can accommodate fully loaded vessels of class 2. or less.

The IGLLB assumed that by 1995 67% of grain that is transported will be in vessels of class 7 or better, and that by 2020 all grain will be transported by vessels of class 6 or better, with 74% of the grain being transported in vessels of class 7 or better (IGLLB 1973, Appendix E, p. E-47). Since, at the present time, eleven of the twelve ports (91%) can only accommodate fully loaded vessels of class 5 or less, it is again apparent that massive dredging and renovation of the docking facilities will have to be made if these assumptions are to become valid in the future.

Wisconsin Ports

Looking at the twenty-two harbors of Wisconsin, only two (9%) have harbors and docking facilities with depths of 27 feet. These two ports are Milwaukee and Superior. Furthermore, it appears that the majority of ships inbound/outbound from each of these two harbors utilize a draft of much less than 27 feet. In Milwaukee, 92% of the ships going into/leaving the port have a draft of 20 feet or less; while 83% of the ships entering/leaving the port of Duluth-Superior had a draft of 25 feet or less. Looking at the twenty shallow draft harbors in Wisconsin, ten of these twenty harbors (50%) recorded ships entering/leaving their respective harbors with drafts of twenty feet or less. It is apparent that Wisconsin harbors are, for the majority of the time, utilized by vessels having a shallow water draft.

In looking at the four major commodities and the various ports that handle the shipment and receipt of them, it is apparent that a good number of them limit the vessel size that can fully utilize their facilities. Only in the case of ports handling iron ore is there a substantial number of "deep-water drafts" —100% of the loading facilities and 77% of the unloading ports. For the remaining major commodities, there is a high percentage of shallow draft ports. In the case of coal 43% of the loading ports and 93.6% of the unloading ports are shallow draft harbors. In the case of limestone 61% of the loading ports and 50% of the unloading ports are shallow draft harbors. In the case of grain 67% of the ports are shallow draft ports.

If the assumption that all harbors will have a minimum draft of 27 feet by 1995 is to become valid, massive dredging and harbor renovation will have to take place within the two decades.* Serious questions will be raised as to the feasibility of such an undertaking, such as a) the tremendous cost that would be involved; b) the environmental considerations from massive dredgings, and c) lowering of the mean lake level by the increased channel depth.

It should be pointed out that, in this analysis, two assumptions were made. One was that the water levels were at LWD, and the other was that ships were loaded to their maximum capacity. It is clear that water levels, for the most part, tend to be above or at least equal to LWD. At the present time, the water levels are quite high on the lakes, thus vessels are not as readily subject to the shallow water draft limitations of the channels and harbors. Also, it is quite evident that vessels do not load to their maximum capacity, but to the limitations placed upon it by the channel and loading/unloading limitations that it will encounter along its route. As in the case of grain for overseas transport, the shipmasters know that the prime limiting factor is the Welland Canal—thus they see to it that their vessel is loaded accordingly, in order to comply with the limitations that it will encounter.

It still is evident that these shallow draft harbors do place limitations on the size of the vessel that may enter it if not by its channel depth, then by its overall ship length limitations.**

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* There has been some consideration to enlarging the navigational locks and channels to a 32' depth and 1,200 x 110 lock dimensions to accommodate the "super ships" now under construction. Cost of such an undertaking has been conservatively estimated at $4 billion (Great Lakes Basin Commission 1975).

** At the present time, these limitations are not much of a limiting factor. However, if just dredging of the harbors is undertaken in the future, the overall length limitations will become a significant factor in limiting the ship classes that would enter these ports.

ATTACHMENT E

ROUTES AND TRIP COSTS

The curious fluctuations in the cost of transporting coal and iron ore, where the cost per ton increases with increasing ship class between class 4 and class 5 and again between class 6 and class 7 (class 7 data for 1995 rather than 1970), probably emphasizes the approximate nature of the data in Table E-26 of the IGLLB report, rather than being a reflection of an unusual diseconomy (IGLLB 1973, Appendix E, p. E-72). The assumption that coal and limestone carrying ships that are now more fully utilized will be operated empty for over half their trips in the future should be questioned.

In Table 34 the average dollars per trip are calculated assuming the distribution of ships travelling each route is that given in the third column of Table E-33 (IGLLB 1973, Appendix E, p. E-77). All traffic on any route is calculated as if it were carried over the longest route.

Savings or losses resulting from lake levels greater or less than the required level are calculated using vessel expenses only, excluding fixed costs. This seems a more appropriate measure of the costs or benefits resulting from any particular set of lake levels. Thus, if regulation changes the lake levels such that a particular route will be able to gain or lose cargo measured in tenths of a foot this can be multiplied by the dollars in the last column to obtain an estimate of the benefits.

Table 30 Iron Ore — U.S. Fleet — 1970

ROUTE (4)	DISTANCE	CLASS	TIME/TRIP *	COST/TRIP (1)	COST/TRIP (2)	COST/TON (1)	% max. cargo per ft immersion
S-M	797 mi.	4	118.5 hrs.	$32,106	$20,580	$2.57	5.8%
		5		36,134	22,258	2.10	5.8
		6	129.9	42,073	25,497	1.85	5.4
		7		44,801	26,612	1.65	5.1
		8 (3)	103.8	47,005	28,062	1.05	4.8
		9 (3)	105.8	47,911	28,891	.94	4.5
		10 (3)	107.8	60,672	36,403	.98	4.3
S-E	792	less than 1% difference from S-M figures					
M-H	276	4	51.49	13,953	8,944	1.12	5.8
		5		15,703	9,673	.91	5.8
		6	55.4	17,959	10,883	.79	5.4
		7		19,123	11,359	.70	5.1
		8 (3)	42.5	19,239	11,486	.43	4.8
		9 (3)	44.5	21,524	12,979	.42	4.5
		10 (3)	46.5	26,163	15,978	.42	4.3
M-E	507	4	81.2	22,001	14,103	1.76	5.8
		5		24,762	15,253	1.44	5.8
		6	88.4	28,651	17,362	1.26	5.4
		7		30,507	18,122	1.12	5.1
		8 (3)	69.6	31,550	18,835	.70	4.8
		9 (3)	71.6	34,677	20,910	.68	4.5
		10 (3)	73.6	41,463	24,878	.67	4.3
S-O	971	4	140.8	38,168	24,466	3.05	5.8
		5		42,957	26,462	2.50	5.8
		6	154.7	50,127	30,377	2.20	5.4
		7		53,376	31,706	1.96	5.1
		8 (3)	124.2	56,279	33,598	1.25	4.8
		9 (3)	126.2	61,098	36,842	1.20	4.5
		10 (3)	128.2	72,196	43,318	1.16	4.3

*Includes time factor from Table E-26 (IGLLB 1973, Appendix E, p. E-72), to allow for percentage of time ship runs empty or partially empty.

Notes: (1) Includes all costs listed as daily fixed charges and vessel expenses, Table E-14(IGLLB, Appendix E, p. E-54).
(2) Includes only expenses listed as vessel expenses and excludes fixed charges.
(3) From Table E-34 (IGLLB, Appendix E, p. E-78), information for U.S. Fleet, 1995.
(4) M-H - Lake Michigan to Lake Huron; S-M - Lake Superior to Lake Michigan; S-E - Lake Superior to Lake Erie; S-0 - Lake Superior to Lake Ontario; M-E - Lake Michigan to Lake Erie.

Table 31 Grain — U.S. Fleet — 1970

ROUTE (4)	DISTANCE	CLASS	TIME/TRIP *	COST/TRIP (1)	COST/TRIP (2)	COST/TON (1)	% mx. cargo/ foot immersion
S-O	1334 mi.	2	216.1	44,301	28,840	4.89	5.9
		3		50,351	32,023	3.96	5.8
		4	187.5	50,816	32,573	3.97	5.9
		5		57,192	35,230	3.89	5.8
		6(3)	206.6	66,929	40,559	2.79	5.1
		7(3)		71,267	42,333	2.47	4.8
		N.B. The capacity of a class 5 grain carrying ship in 1995 is listed as much greater than the same class ship in 1970.					
		5(3)	187.5	57,192	35,230	2.51	5.1
S-M	808	2	137.2	28,126	18,310	3.09	5.9
		3		31,968	20,331	2.52	5.8
		4	119.9	32,489	20,825	2.54	5.9
		5		36,565	22,524	2.49	5.8
		6(3)	131.4	42,583	25,805	1.77	5.1
		7(3)		45,343	26,934	1.57	4.8
		N.B.5	119.9	36,565	22,524	1.60	5.1
S-E	986	2	163.9	33,600	21,873	3.69	5.9
		3		38,189	24,288	3.01	5.8
		4	142.8	38,691	23,834	3.02	5.9
		5		43,545	26,824	2.96	5.8
		N.B.5(3)				1.91	5.1
		6(3)	156.9	50,822	30,798	2.12	5.1
		7(3)		54,116	32,145	1.87	4.8
S-O	1025	2	169.8	34,799	22,654	3.82	5.9
		3		39,552	25,155	3.11	5.8
		4	147.8	40,050	25,672	3.13	5.9
		5		45,075	27,766	3.07	5.8
		5(3)				1.98	5.1
		6(3)	162.4	52,627	31,892	2.19	5.1
		7(3)		56,038	33,286	1.94	4.8
M-H	535	2	96.3	19,731	12,845	2.17	5.9
		3		22,426	14,263	1.77	5.8
		4	84.8	22,977	14,728	1.80	5.9
		5		25,860	15,930	1.76	5.8
		5(3)				1.13	5.1
		6(3)	92.4	29,947	18,447	1.25	5.1
		7(3)		31,888	18,941	1.10	4.8
M-E	893	2	150.0	30,740	20,012	3.38	5.9
		3		34,938	22,221	2.75	5.8
		4	130.8	35,451	22,724	2.77	5.9
		5		39,898	24,577	2.71	5.8
		5(3)				1.75	5.1
		6(3)	143.6	46,517	28,189	1.94	5.1
		7(3)		49,532	29,422	1.71	4.8
M-O	1200	2	196.0	40,180	26,157	4.42	5.9
		3		45,668	29,045	3.60	5.8
		4	170.3	46,147	29,581	3.60	5.9
		5		51,937	31,993	3.53	5.8
		5(3)				2.28	5.1
		6(3)	187.4	60,727	36,800	2.53	5.1
		7(3)		64,663	38,410	2.24	4.8
E-E	254	2	54.1	11,091	7,220	1.22	5.9
		3		12,605	8,017	.99	5.8
		4	48.7	13,186	8,452	1.03	5.9
		5		14,840	9,142	1.01	5.8
		5(3)				.65	5.1
		6(3)	52.3	16,941	10,266	.71	5.1
		7(3)		18,039	10,715	.62	4.8
E-O	561	2	100.2	20,531	13,366	2.26	5.9
		3		23,335	14,841	1.84	5.8
		4	88.1	23,883	15,309	1.87	5.9
		5		26,879	16,558	1.83	5.8
		5(3)				1.18	5.1
		6(3)	96.1	31,150	18,877	1.30	5.1
		7(3)		33,169	19,703	1.15	4.8

*Includes time factor from Table E-26 (IGLLB 1973, Appendix E, p. E-72), to allow for percentage of time ship runs empty or partially empty.

Notes: (1) Includes all costs listed as daily fixed charges and vessel expenses, Table E-14 (IGLLB, Appendix E, p. E-54).
(2) Includes only expenses listed as vessel expenses and excludes fixed charges.
(3) From Table E-34 (IGLLB, Appendix E, p. E-78), information for U.S. Fleet, 1995.
(4) M-H - Lake Michigan to Lake Huron; S-M - Lake Superior to Lake Michigan; S-E - Lake Superior to Lake Erie; S-O - Lake Superior to Lake Ontario; M-E - Lake Michigan to Lake Erie.

TABLE 32 COAL — U.S. FLEET — 1970

ROUTE (4)	DISTANCE	CLASS	TIME/TRIP *	COST/TRIP (1)	COST/TRIP (2)	COST/TON (1)	% max. cargo/ ft immersion
M-M	126 mi.	2	23.1 hrs.	$ 4,741	$ 3,086	$ .80	7.1%
		3		5,388	3,427	.52	6.0
		4	21.3	5,759	3,691	.45	5.9
		5	32.2	9,821	6,050	.66	6.3
		6 (3)	34.0	11,016	6,676	.51	5.6
		7 (3)	34.0	11,730	6,968	.54	6.3
M-H	533	2	65.5	13,432	8,744	2.28	7.1
		3		15,266	9,709	1.48	6.0
		4	57.6	15,607	10,004	1.21	5.9
		5	84.5	25,781	15,881	1.73	6.3
		6 (3)	92.1	29,854	17,733	1.37	5.6
		7 (3)		31,789	18,883	1.45	6.3
E-S	717	2	84.7	17,361	11,302	2.94	7.1
		3		19,732	12,550	1.92	6.0
		4	74.0	20,059	12,858	1.56	5.9
		5	108.2	32,997	20,326	3.33	6.3
		6 (3)	118.4	38,371	23,253	1.76	5.6
		7 (3)		40,858	24,270	1.87	6.3
E-M	628	2	75.4	15,460	10,065	2.62	7.1
		3		17,572	11,176	1.71	6.0
		4	66.1	17,905	11,477	1.39	5.9
		5	96.7	29,507	18,176	1.98	6.3
		6 (3)	105.7	34,251	20,756	1.57	5.6
		7 (3)		36,471	21,664	1.67	6.3
E-H	239	2	34.9	7,154	4,657	.21	7.1
		3		8,131	5,171	.79	6.0
		4	31.3	8,493	5,444	.66	5.9
		5	46.7	14,252	8,779	.96	6.3
		6 (3)	50.1	16,246	9,845	.75	5.6
		7 (3)		17,299	10,276	.79	6.3
E-E	94	2	19.8	4,057	2,641	.69	7.1
		3		4,611	2,933	.45	6.0
		4	18.4	4,984	3,195	.39	5.9
		5	28.1	8,566	5,277	.58	6.3
		6 (3)	29.4	9,535	5,778	.44	5.6
		7 (3)		10,153	6,031	.46	6.3
E-O	237	2	34.7	7,111	4,629	1.21	7.1
		3		8,082	5,140	.79	6.0
		4	31.2	8,445	5,413	.66	5.9
		5	46.5	14,174	8,731	.95	6.3
		6 (3)	49.9	16,154	9,789	.74	5.6
		7 (3)		17,210	10,217	.79	6.3
O&St.L-O	117	2	22.2	4,548	2,961	.77	7.1
		3		5,170	3,288	.50	6.0
		4	20.4	5,541	3,552	.43	5.9
		5	31.0	9,468	5,832	.64	6.3
		6 (3)	32.7	10,599	6,296	.49	5.6
		7 (3)		11,286	6,704	.52	6.3

*Includes time factor from Table E-26 (IGLLB 1973, Appendix E, p. E-72), to allow for percentage of time ship runs empty or partially empty.

Notes: (1) Includes all costs listed as daily fixed charges and vessel expenses, Table E-14 (IGLLB, Appendix E, p. E-54).
(2) Includes only expenses listed as vessel expenses and excludes fixed charges.
(3) From Table E-34 (IGLLB, Appendix E, p. E-78), information for U.S. Fleet, 1995.
(4) M-H - Lake Michigan to Lake Huron; S-M - Lake Superior to Lake Michigan; S-E - Lake Superior to Lake Erie; S-O - Lake Superior to Lake Ontario; M-E - Lake Michigan to Lake Erie.

TABLE 33 LIMESTONE — U.S. FLEET —1970

ROUTE (4)	DISTANCE	CLASS	TIME FACTOR Per TRIP*	COST/TRIP (1)	COST/TRIP (2)	COST/TON (1)	% max. cargo/ ft immersion
S-H	158 mi.	2	26.5	5,424	3,531	.79	6.1%
		3		6,154	3,921	.59	6.0
		4	24.1	6,533	4,188	.50	5.8
		5	36.3	11,076	6,823	.68	5.7
		6[3]	38.6	12,497	7,573	.52	5.1
		7[3]		13,307	7,904	.46	4.8
		8[3]	32.6	14,755	8,809	.33	4.8
		9[3]	34.6	16,733	10,090	.33	4.5
S-E	452	2	57.1	11,702	7,618	1.70	6.1
		3		13,300	8,459	1.28	6.0
		4	50.4	13,647	8,748	1.05	5.8
		5	74.1	22,605	13,925	1.38	5.7
		6[3]	80.6	26,105	15,820	1.09	5.1
		7[3]		27,797	16,512	.96	4.8
		8[3]	74.6	33,781	20,167	.75	4.8
		9[3]	76.6	37,061	22,348	.73	4.5
M-M	268	2	37.9	7,773	5,060	1.13	6.1
		3		8,835	5,619	.85	6.0
		4	33.9	9,195	5,894	.71	5.8
		5	50.5	15,389	9,480	.94	5.7
		6[3]	54.3	17,589	10,659	.73	5.1
		7[3]		18,729	11,125	.65	4.8
		8[3]	48.3	21,873	13,058	.49	4.8
		9[3]	50.3	24,338	14,676	.48	4.5
M-H	279	2	39.1	8,008	5,213	1.16	6.1
		3		9,102	5,789	.88	6.0
		4	34.9	9,461	6,064	.73	5.8
		5	51.9	15,821	9,746	.97	5.7
		6[3]	55.9	18,098	10,967	.75	5.1
		7[3]		19,271	11,447	.67	4.8
		8[3]	49.9	22,585	13,483	.50	4.8
		9[3]	51.9	25,099	15,135	.49	4.5
M-E	462	2	58.1	11,916	7,757	1.73	6.1
		3		13,543	8,613	1.30	6.0
		4	51.3	13,889	8,903	1.07	5.8
		5	75.4	22,997	14,166	1.40	5.7
		6[3]	82.0	26,568	16,100	1.11	5.1
		7[3]		28,290	16,889	.98	4.8
		8[3]	76.0	34,428	20,554	.77	4.8
		9[3]	78.0	37,752	22,764	.74	4.5
H-S	426	2	54.4	11,147	7,257	1.62	6.1
		3		12,669	8,058	1.22	6.0
		4	48.0	13,018	8,344	1.00	5.8
		5	70.8	21,585	13,297	1.32	5.7
		6[3]	76.9	24,902	15,090	1.04	5.1
		7[3]		26,516	15,830	.92	4.8
		8[3]	70.9	32,098	19,163	.71	4.8
		9[3]	72.9	35,263	21,264	.69	4.5
H-M	364	2	47.9	9,823	6,395	1.42	6.1
		3		11,165	7,101	1.07	6.0
		4	42.5	11,518	7,383	.89	5.8
		5	62.8	19,154	11,799	1.17	5.7
		6[3]	68.0	22,032	13,351	.92	5.1
		7[3]		23,460	14,006	.81	4.8
		8[3]	62.0	28,086	16,767	.62	4.8
		9[3]	64.0	30,976	18,679	.61	4.5
H-H	132	2	23.8	4,869	3,170	.71	6.1
		3		5,534	3,519	.53	6.0
		4	21.8	5,904	3,784	.45	5.8
		5	33.0	10,056	6,195	.61	5.7
		6[3]	34.9	11,294	6,844	.47	5.1
		7[3]		12,026	7,179	.42	4.8
		8[3]	28.9	13,072	7,804	.29	4.8
		9[3]	30.9	14,935	9,006	.29	4.5
H-E	354	2	46.9	9,609	6,256	1.39	6.1
		3		10,922	6,946	1.05	6.0
		4	41.6	11,276	7,228	.87	5.8
		5	61.5	18,762	11,558	1.14	5.7
		6	66.6	21,569	13,071	.90	5.1
E-S	481	2	60.1	12,321	8,021	1.79	6.1
		3		14,004	8,907	1.35	6.0
		4	52.9	14,348	9,197	1.10	5.8
		5	77.8	23,742	14,625	1.45	5.7
		6	84.7	27,447	16,633	1.14	5.1
E-H	129	2	23.4	4,804	3,128	.70	6.1
		3		5,461	3,473	.53	6.0
		4	21.5	5,831	3,738	.45	5.8
		5	32.6	9,939	6,122	.61	5.7
		6	34.4	11,154	6,760	.47	5.1
E-E	62	2	16.5	3,374	2,196	.49	6.1
		3		3,835	2,439	.37	6.0
		4	15.5	4,210	2,699	.32	5.8
		5	24.0	7,311	4,504	.45	5.7
		6	24.9	8,054	4,881	.34	5.1
E-O	160	2	26.7	5,467	3,559	.79	6.1
		3		6,213	3,952	.60	6.0
		4	24.3	6,581	4,219	.51	5.8
		5	36.6	11,154	6,871	.68	5.7
		6	38.9	12,590	7,629	.53	5.1

*Includes time factor from Table E-26 (IGLLB 1973, Appendix E, p. E-72), to allow for percentage of time ship runs empty or partially empty.

Notes: (1) Includes all costs listed as daily fixed charges and vessel expenses, Table E-14 (IGLLB, Appendix E, p. E-54).
(2) Includes only expenses listed as vessel expenses and excludes fixed charges.
(3) From Table E-34 (IGLLB, Appendix E, p. E-78), information for U.S. Fleet, 1995.
(4) M-H - Lake Michigan to Lake Huron; S-M - Lake Superior to Lake Michigan; S-E - Lake Superior to Lake Erie; S-O - Lake Superior to Lake Ontario; M-E - Lake Michigan to Lake Erie.

TABLE 34 SAVING OR LOSS PER 0.1 FOOT CHANGE IN LAKE LEVEL OVER A SHIPPING SEASON

ROUTE	DISTANCE	TONNAGE (10^6net tons)	NET TONS/ TRIP	# TRIPS	TONS + or - per .1 ft LEVEL CHANGE	# TRIPS ± per .1 ft LEVEL CHANGE	AVERAGE $ PER TRIP	SAVINGS/LOSS per .1 ft LEVEL CHANGE FOR SEASON
S-M	797 mi	24.2	18,278	1,324.0	103	7.44	$22,828	$169,858
S-E	792	41.56		2,273.8		12.78		291,706
S-O	971	.38		20.8		.12	27,152	3,150
M-M	276	3.45		188.8		1.06	9,882	10,483
M-E	507	3.39		185.5		1.88	15,622	29,401
OSL-M	1172	.43		23.5		.13	32,147	4,250
OSL-E	416	1.42		77.7		.44	13,361	5,835
				COAL				
M-M	126	9.27	14,082	658.3	83	3.96	4,818	19,075
M-H	533	.60		42.4		.26	12,936	3,315
E-S	717	5.13		364.3		2.19	16,691	36,563
E-M	628	2.94		208.8		1.26	14,902	18,709
E-H	239	16.98		1,205.8		7.25	7,088	51,397
E-E	94	18.70		1,327.9		7.99	4,176	33,346
E-O	237	1.64		116.5		.70	7,048	4,936
OSL-O	117	.04		2.8		.02	4,618	79
				LIMESTONE				
S-H	158	.29	15,006	19.3	85	.11	5,462	596
S-E	452	5.91		393.8		2.22	11,367	25,263
M-M	268	12.25		816.3		4.61	7,671	35,339
M-H	279	5.45		383.2		2.05	7,892	16,175
M-E	462	6.86		457.2		2.58	11,537	29,762
H-S	426	4.11		273.9		1.55	10,845	16,762
H-M	364	17.31		1,153.5		6.51	9,600	62,489
H-H	132	7.74		515.8		2.91	4,939	14,376
H-E	354	15.21		1,013.6		5.72	9,399	53,760
E-S	581	.04		2.7		.02	11,950	180
E-H	129	.23		15.3		.09	4,879	422
E-E	62	8.70		1,246.2		7.03	3,533	24,847
E-O	160	.04		2.7		.02	5,502	83
				GRAIN				
S-M	808	.05	12,883	3.9	79	.02	21,485	508
S-E	986	2.79		216.6		1.32	25,298	33,400
S-O	1,334	.92		71.4		.44	33,639	14,645
M-H	535	.02		1.6		----	15,177	144
M-E	893	.54		41.9		.26	23,449	5,992
M-O	1,200	1.05		81.5		.50	30,543	15,175
E-E	254	.19		14.8		.09	8,684	781
E-O	561	.64		49.7		.30	15,778	4,779
								1,027,496

ATTACHMENT F

TABLES OF WISCONSIN WATERBORNE COMMERCE

Eleanor Hobbs

Five harbors account for the greatest proportion of receipts and shipments through Wisconsin ports. Tables 35-38 detail the major commodities received and shipped, and compare the total for these five harbors to the statewide total. Additional important receiving and shipping harbors are tabled with respect to the major commodities handled.

TABLE 35 RECEIPTS AT WISCONSIN HARBORS — 1970 (NET TONS)

Harbor Commodity	Duluth-Superior	Green Bay	Kewaunee	Manitowoc	Milwaukee	Total
Iron Ore						
Coal	1,816,125	1,890,055	6,573	188,863	1,662,159	5,563,775
Limestone	939,911	172,364	128	50,652	272,686	1,435,741
Grain	24,764		34	32,431	197,461	254,690
Subtotal	2,780,800	2,062,419	6,734	271,946	2,132,306	4,254,206
Fresh Fish						
Nonmetallic minerials	100,361	41,641	55,238	62,655	303,794	563,689
Dried milk, cream			148	117	941	1,206
Pulp		45,826	3,620	21,976	70,694	142,116
Paper, paperboard	56		21,477	54,277	22,988	98,798
Wood, wood products	1	8	22,320	8,661	68,101	99,091
Gasoline, fuel oil	141,621	241,690	37,161		786,068	1,206,540
Building cement	474,413	205,892	785	355,065	461,344	149,749
Motor vehicles, parts	35		60,621	12,853	130,335	203,844
Chemicals	9,149	6,087	22,134	51,417	103,995	192,782
Iron, steel scrap			120	1,229	12,999	13,648
Subtotal	725,636	541,144	223,624	568,250	1,960,559	4,019,213
List Total	3,506,436	2,603,563	230,349	840,196	3,306,797	11,273,419
Harbors Total	3,682,998	2,739,575	412,512	1,144,325	5,073,671	13,053,081

Harbor Commodity	Menominee	Detroit	Racine	Sheyboygan	Other	Total
Iron Ore						
Coal	106,008	17	10,280	92,981	2,597,573*	2,806,859
Limestone	55,333					55,333
Grain					20	Kenosha20
Subtotal	161,341	17	10,280	92,981	2,597,593	3,862,212
Fresh Fish						
Nonmetallic minerials	23,601		28,170	13,575		65,346
Dried milk, cream	20					20
Pulp	84,036					84,036
Paper, paperboard	83					83
Wood, wood products	1,218	557			55,183	56,958 Ashland
Gasoline, fuel oil		2,934	77,910	35,312	101,457	217,613 Two R.
Building cement		248			166,647	166,895 Pt. Ws.
Motor vehicles, parts		69			19	88 Ashland
Chemicals						
Iron, steel scrap						
Subtotal	108,958	3,808	106,080	48,887	323,306	591,039
List Total	270,299	3,825	116,360	141,868	2,920,899	3,453,251
Harbors Total	287,008	7,679	117,377	190,277	3,459,641	4,061,982

Source: U.S. Army Crops of Engineers 1970.

* Ashland (356,263), Port Washington (1,023,143), Oak Creek (1,218,167).

TABLE 36 SUMMARY: RECEIPTS AT WISCONSIN HARBORS — 1970

Commodity	FIVE HARBORS* Net Tons	As % of State Total	OTHER HARBORS Net Tons	As % of State Total
Iron Ore				
Coal	5,564,000	32.5	2,807,000	16.4
Limestone	1,436,000	8.4	55,000	.3
Grain	255,000	1.5	20	<.1
Subtotal	7,254,000	42.4	2,862,000	16.7
Fresh Fish				
Nonmetallic minerials	564,000	3.3	65,000	.4
Dried milk, cream	1,200	<.1	20	<.1
Pulp	142,000	.8	84,000	.5
Paper, paperboard	98,800	.6	80	<.1
Wood, wood products	99,100	.6	57,000	.3
Gasoline, fuel oil	1,206,500	7.1	218,000	1.3
Building cement	1,497,500	8.8	167,000	1.0
Motor vehicles, parts	203,800	1.2	90	<.1
Chemicals	192,800	1.1		
Iron, steel scrap	13,600	<.1		
Subtotal	4,019,200	23.5	591,000	3.45
List Total	11,273,000	65.9	3,453,000	20.2
Harbors Total	13,053,000	76.3	4,052,000	23.7

Source: U.S. Army Corps of Engineers 1970.

* Duluth-Superior, Green Bay, Kewaunee, Manitowoc, and Milwaukee.

TABLE 37 SHIPMENTS FROM WISCONSIN HARBORS — 1970 (NET TONS)

Harbor Commodity	Duluth-Superior	Green Bay	Kewaunee	Manitowoc	Milwaukee	Total
Iron Ore	32,352,205					
Coal		17	216	2,248	10,135	32,352,205
Limestone			225	86		12,616
Grain	5,973,978		32	5,896	530,106	6,510,012
Subtotal	38,326,183	17	473	8,230	540,241	38,875,144
Fresh Fish	639*	902*	5*	10*	1,079*	2,635
Nonmetallic minerials			5,987	6,745	70	12,805
Dried milk, cream	49,834	5,127	12,653	5,151	19,151	91,826
Pulp			15,386	42,562	12,840	70,788
Paper, paperboard	126		191,320	318,827	21,071	531,344
Wood, wood products	8		257,324	153,339	70,355	481,026
Gasoline, fuel oil	135,905	5,000				140.905
Building cement			101	3,040	9,489	12,630
Motor vehicles, parts	58		5,115	2,834	170,642	178,649
Chemicals	49,946		36,313	150,393	4,860	241,512
Iron, steel scrap	98,911		143	1,003	146,666	246,723
Subtotal	335,427	11,029	524,257	683,904	456,223	2,010,840
List Total	38,661,610	11,046	526,080	692,134	996,464	40,889,784
Harbors Total	39,075,328	51,262	882,995	1,248,402	1,905,363	43,164,350

Harbor Commodity	Bayfield	La Pointe	Menominee	Kenosha	Other**	
Iron Ore						
Coal	No shipments of these major bulk commodities					
Limestone		from minor harbors.				
Grain						
Subtotal						
Fresh Fish	834*	6*	1,868*	298*	10,845*	13,851
Nonmetallic minerials						
Dried milk, cream			38			38
Pulp						
Paper, paperboard			557			557
Wood, wood products			1,134	77		1,211
Gasoline, fuel oil	198	198				396
Building cement						
Motor vehicles, parts						
Chemicals				17		17
Iron, steel scrap						
Subtotal	1,032	204	3,597	392	10,845	16,070
List Total	1,032	204	3,597	392	10,845	16,070
Harbors Total	6,769	5,878	1,868 86,303	24,696	10,845	136,459

Source: U.S. Army Corps of Engineers 1970.

* Fresh fish represents, for the most part, local traffic only.

** From ports whose only shipment of listed commodities is fresh fish: Algoma (879), Detroit Harbor (170), Oconto (1511), Pensaukee (2202), Two Rivers (3880), Racine (1017), Sheboygan (66), Port Washington (155), Ashland (4), Cornucopia (90), Port Wing (235). Total (10,845).

TABLE 38 SUMMARY: SHIPMENTS FROM WISCONSIN HARBORS — 1970

Commodity	FIVE HARBORS* Net Tons	As % of State Total	OTHER HARBORS Net Tons	As % of State Total
Iron Ore	32,352,000	74.7		
Coal	12,600	<.1		
Limestone	300	<.1		
Grain	6,510,000	15.0		
Subtotal	38,875,000	89.8		
Fresh Fish*	2,600	<.1	13,900	<.1
Nonmettalic minerials	13,000	<.1		
Dried milk, cream	92,000	.2		<.1
Pulp	71,000	.2		<.1
Paper, paperboard	531,000	1.2		<.1
Wood, wood products	481,000	1.1		.1
Gasoline, fuel oil	140,900	.3		
Building cement	12,600	<.1		
Motor vehicles, parts	178,600	.4		
Chemicals	242,000	.6		<.1
Iron, steel scrap	247,000	.6		
Subtotal	2,011,840	4.6		<.1
List Total	40,886,000	94.4		<.1
Harbors Total	43,164,000	99.7		

Source: U.S. Army Corps of Engineers 1970.

* Duluth-Superior, Green Bay, Kewaunee, Manitowoc, and Milwaukee.

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